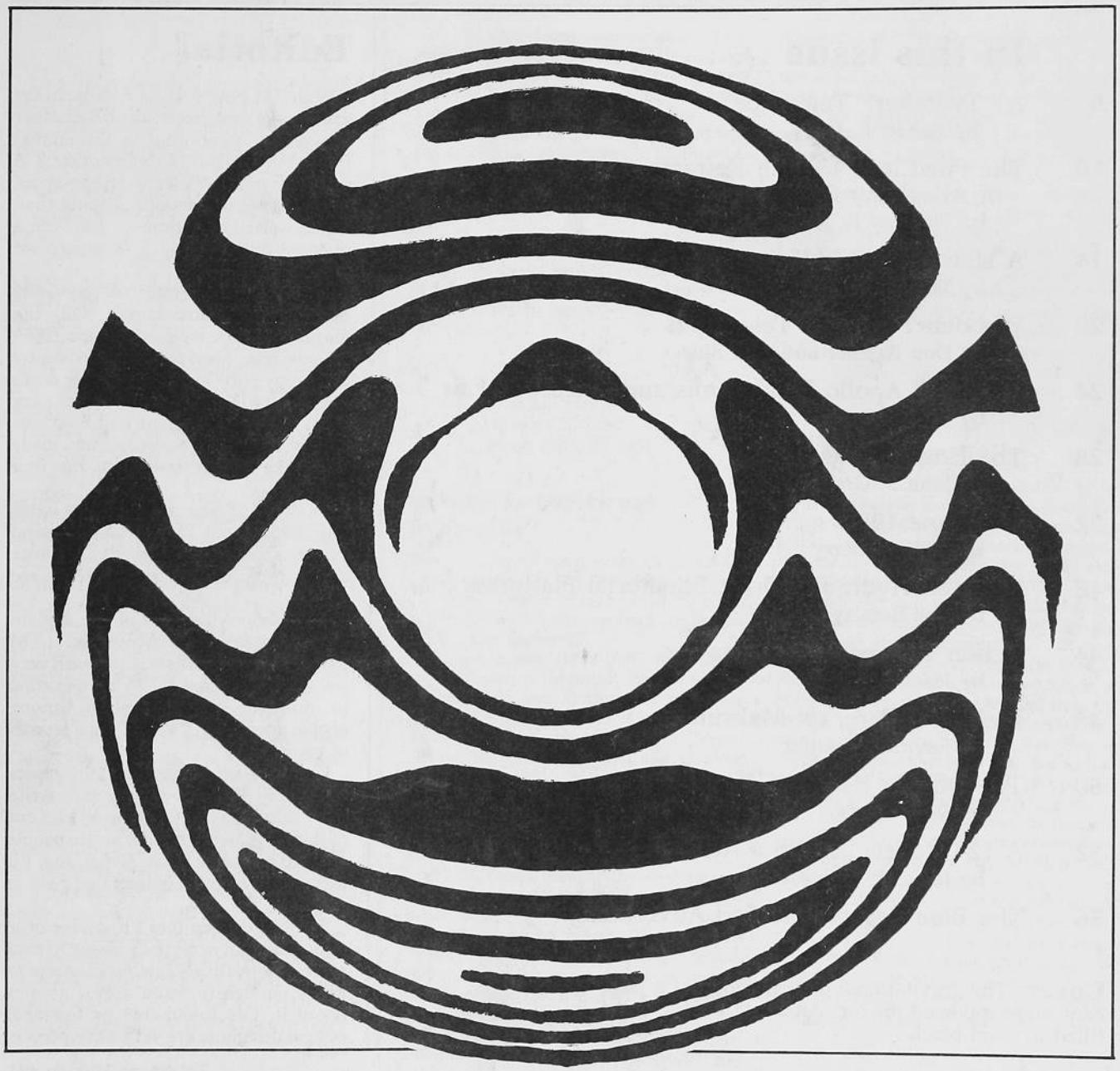
TELESCOPE MAKING 21

ISSN 0190-5570

The magazine *for*, *by*, and *about* telescope makers!

Winter 1983



TELESCOPE MAKING

The magazine *for, by,* and *about* telescope makers!

Editor: Richard Berry

Associate Editor: Robert E. Cox

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Editorial

With TM now past its fifth birthday and firmly established in the amateur community (according to the annual *Index to How To Do It Information*, TM publishes more articles and pages about telescopes and telescope making than anyone else!), it's time to stop for a moment and take stock of where we stand.

TM readers who write to me generally seem to be pretty happy with the magazine. Since we don't have a 100% renewal rate, some people are evidently not happy with TM, but I usually don't hear from them. In most cases, my guess is that they never had a serious interest in building telescopes and made a mistake by subscribing in the first place.

Anyhow, if you aren't happy with something about TM, I wouldn't mind hearing about it from you. I'll make sure that letters of general interest are printed.

Two underlying facts of life explain a lot about the way TM works: 1) TM publishes what readers send, with very few exceptions; and 2) TM is a magazine to promote communication among people interested in a field, not a journal of record.

If you want to see certain topics covered in TM, it's up to you to write those articles. I can't conjure articles out of thin air. Once I become aware people want to see more about something, I'll do my best to get people in that field to write for TM.

The biggest gap that I'm aware of is optical design: everybody wants to read more, but relatively few people seem to know enough to write useful articles about it. I've found that professional optical designers are very busy people.

If they don't want to write an article, I can't make them write one. Therefore, if you want to read about something, it becomes your responsibility, as part of the telescope making community, to learn about it and then, after you've learned about it, to sit down and write about it for others.

TM is not a "journal of record." That means that you can't take as gospel truth every word you see printed in its pages. Heaven forbid. My more modest hope is that TM can bring people together, stimulate thinking, and act as a medium for interchange of ideas. When someone writes an article for TM, we can't send it out to referees or verify every fact and statement in it, then send it back to the author for rewriting until it's perfect. (The main exceptions are articles about geometric optics and construction formulae, where we try to verify the accuracy of the content and equations.)

If we had to do all that work for every article, your subscription to TM would cost $50 a year, or more likely TM would not exist at all. We're happy to print corrections, but hope that you as intelligent beings have the sense to read critically and think about what you have read.

Even in the few years since TM started, telescope making has changed as a hobby. One complaint I hear is that we don't run enough on fabricating fancy optics. One person even complained that "TM started out well but has gone downhill ever since." I sympathize, but as far as I can tell, there are very few people out there making anything but paraboloidal mirrors for Newtonians, and there are many fewer of them now than there were a few years ago. I suppose that there isn't much to say about making an 8" mirror that hasn't been said before, or, if there is, then those people doing it think that nobody else wants to hear them say it.

Maybe that's going to change. Willmann-Bell is bringing out a new edition (revised and expanded) of Jean Texereau's *How To Make a Telescope*. I can hear you saying, "Oh, goody!" I have just finished my own *Build Your Own Telescope*, a book with lots of new ideas that's intended for the telescope beginner's market, to be published by Charles Scribner's Sons next Fall. I hope lots of libraries buy it, because that way people who have never even thought about telescopes before will check it out and catch the TM bug. And I have heard that *The Standard Handbook of Telescope Making* is being revised and will be re-issued. Perhaps things will start rolling again.

Homebuilt MCTs and SCTs are rarer

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Letters

A New Subscriber

Dear Richard / My first isssue of *Telescope Making* was #19. After reading every word, I promptly sent for all the back issues. This is a fantastic magazine! My workshop will never be the same!

Now that I've buttered you up, I'll drop the other shoe. Why are you withholding information? A good source of hard-to-find parts is hard to find — and the letter in TM#15 from Earle Dodds, about Small Parts, Inc., leads me to believe that they would be ideal. After poring over that issue and all the others up to and including #20, I've concluded that I'm blind or else you have neglected to publish the address of Small Parts, Inc. Would you please send me the address. I would hate to have to wait until TM#21 or #22 comes out before I can send for a catalog.

By the way, I saw your variation of the polar disk mount at Stellafane this year and loved it. I am planning to construct one this spring with a clock drive and friction clutch. Thank you for the construction tips.

You're doing a fine job on *Telescope Making* and as long as you publish it, I'll subscribe.

Tom Lloyd
18 Strong St. Ext.
E. Haven, CT 06512

— Oops! Here's the address of Small Parts, Inc. I ordered a whole bunch of knobs and a couple of real cute universal joints from them, as well as the gear and timing chain you saw on the 6" reflector.

Small Parts Inc.
6901 N.E. Third Ave.
P.O. Box 381736
Miami, FL 33138
phone: (305) 751-0856

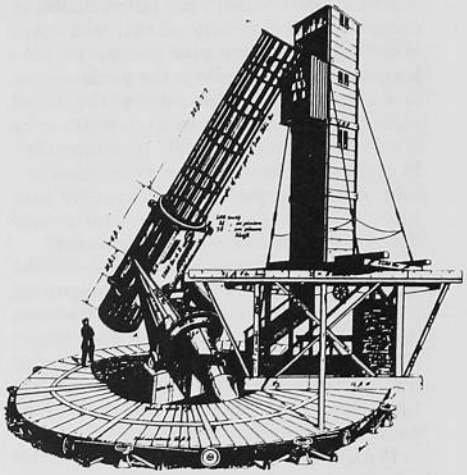
Where Is the Great Reflector?

Dear Sir / Permit me to make an appeal for some information to *Telescope Making*'s readers, which might lead to the whereabouts of what was once the largest telescope in the world.

William Lassell (1799-1880) who hailed from Lancashire, is mainly known for the discovery of four satellites of our solar system: Triton (October 19, 1846); an independent discovery of Hyperion (September 18, 1848); Ariel and Umbriel (October 24, 1851). But Lassell was also a telescope builder. He built a 24-inch reflector in 1844 and in 1859-60; he constructed a Newtonian reflector with a 48" speculum and a focal length of 37 feet.

In 1861, Lassell brought this telescope over to the island of Malta where he spent four years observing satellites and nebulae, assisted by Albert Marth. This so-called "Great Telescope" was the largest optical instrument in the world at the time, having nearly double the size and power of any previous telescope.

It appears that, on completion of the observations in Malta, the telescope was



dismantled since its great size precluded the possibility of transport. However, its exact fate seems to be unknown. William Huggins, in his obituary notice on Lassell, remarks that "It is not possible to suppress a feeling of regret that this magnificient instrument no longer exists" (*Nature*, Vol. 22, pp. 525-6, Oct. 14, 1880).

We would be most interested in obtaining any information regarding the fate of this telescope, particulary of the speculum. From Lasell's own report on his Malta experience (*MNRAS*, Vol. XXXVI, 1867), it appears that there were in fact two specula of 4 feet diameter, different slightly in focal length.

Anna Schembri
Secretary, Students' Astronomical Circle
11, Mons d'Andria Street
Maida, Malta

More on Apodizing

Dear Mr. Berry / I should explain the "blobs of color" that you mention in the Riverside article in *TM#16*. Apodizing filters produce bright, wide radial diffraction spikes, extending pretty well to the edge of the field. These are spectra of the object. They begin a few minutes from the planet, and obscure the rest of the field. Only the Moon is too big to fit down inside the pattern.

Yes, they make a mess of the field. If what you are looking for are planetary details, it doesn't matter; if you are looking to enjoy the overall impression, take off the filter. My new five-layer screen produces less obvious spikes and somewhat less color. For a kick, try the filter on the Pleiades at low power!

The filter can be used to advantage on the Moon, even though the immediate result is a great smear of color. If seeing is very bad, the improvement due to the filter will outweigh the smeariness. As seeing improves, you quickly reach the point where the filter is better removed. But even then, I've sometimes been able to study a small region with better resolution by using the filter. Since the Moon has mostly sharp colorless details, the out-of-focus color blur can be ignored after a while.

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◄3 Letters

Let me also address your rather doubting comment (*TM#19*, Letters) that you don't understand how removal of information (i.e., photons) can contribute to the performance of a scope. May I point out that the use of color filters on cameras and telescopes may also be viewed as "removal" of information. In each case, you are removing unwanted interfering information, and the result is to improve the signal-to-noise ratio and therefore to improve the performance.

I don't think the improvement is due to the "Questar effect." The filter is not an aperture stop. I've tried stops and the result is always diminished resolution. Under poor seeing conditions, you get a steadier image, and that may be useful. But along with it, you will also find that resolution of detail and small contrasts have been decreased.

The Questar effect depends on the fact that a small instrument, due to its limited resolving power, requires less-steady air to reach its maximum performance. But that is not at all the same thing as saying that a small instrument is better than a large one. Stopping down results in a generally more stable image, and that may be very useful. But it will not show the details such as planetary markings, even if you are willing to watch for the moments of good seeing.

My newest apodizing screen works even better than the old one did. I've tried it and the old one on a few nights when the seeing was extremely bad, and on two evenings of fair to good seeing. Both screens were a considerable help. In each case the newer one helped more, and also gave much less obvious diffraction smear. The new screen also gave a somewhat crisper image, with better contrast.

I have not had enough clear nights to try these under various conditions. It may be that each of them works best under different conditions, or maybe one of them will always be the better.

When do I remove the screen? I use it under all conditions, whenever I'm observing planets. It is very rare to have a night of perfect seeing, and the last time that happened, I was so taken staring at Saturn that I made only a single quick comparison. The filter was helping. I should have tried regular filters, too.

I rather wish that you had gone and cobbled one together and tried it first, rather than rejecting it out of hand as he (and nearly everyone else at Riverside) did. When I find time, I'll make a C-8 version and send it to Milwaukee.

Jim Van Nuland
Calico Observatory
3509 Calico Ave.
San Jose, CA 95124

— Jim: Nobody was around Leonard's scope to tell me it had an apodizing screen. I knew what was there from the image. I have made and used apodizing filters for my 8" and 12" reflectors dating back to 1967. I would have appreciated the chance to evaluate the performance of Leonard's telescope without the screen. What I found most frustrating was not the presence of the apodizing screen, but the fact that I couldn't remove it.

I don't think the color filter analogy holds up: the "interfering information" being removed, in this case, is high spatial frequency information, i.e., fine detail in the image. Color filters remove an entirely different kind of interference.

I've gotten one optical expert, and perhaps two, interested in this problem, so perhaps we'll get an explanation of how these filters work someday.

Wright Is Wrong (or Is Wright Right?)

Dear Mr. Berry / The article by Tom Migiel on "Making Correctors for Wright-Newtonian Telescopes" incorrectly describes the Wright system as having a spherical primary mirror. Franklin Wright (in *ATM-2*, p. 402) specifically mentions that the primary mirror is an oblate spheroid, more or less.

Whereas a true Schmidt camera is anastigmatic (free from coma, spherical aberration and astigmatism), the Wright telescope is only aplanatic (free from coma and spherical aberration). The astigmatic field curvatures are such that the best focal surface is flat; this condition is satisfied only when the stop is placed at the focus of the primary mirror, providing the mirror is an oblate spheroid.

Mr. Migiel also says that "since Schmidt cameras are faster than Wright Newtonians, they require deeper curves in the [corrector plate]." This is certainly true, but one must remember that the spherical aberration of an oblate spheroid is twice that of an otherwise equivalent spherical mirror, so that the corrector profile of a Wright telescope requires deeper curves than an equivalent Schmidt system. For example, an f/3 Wright telescope requires a corrector equivalent to an f/2.38 Schmidt camera.

The "Schmidt-Newtonian" described by Mr. Migiel is neither aplanatic nor anastigmatic; it is only free from spherical aberration. It has uncorrected astigmatism

◄3 Editorial

than hen's teeth these days, and no wonder — there's a lot of work involved and the glory is gone. People like me who've been interested in pushing glass for 20 years or so remember when a finely machined 6" catadioptric always drew an admiring crowd. That still happens, but nowadays it's the machining and not the optics that draw the "oohs" and "aahs." But I have noticed that people are very, very interested in image quality again.

Dobsonians opened telescope making for a lot of new people. TM seems to have been responsible for it; at least we're the only outfit that's ever published complete directions for making a Dobsonian. AstroMedia's recent survey shows that about 25% of all Newtonian telescopes in the hands of amateurs are Dobsonians. When you consider that five years ago there were no Dobsonians at all, attaining today's percentage means that somewhat more than half of all the Newtonians built in the last five years had to be Dobsonians. Although some people think nasty thoughts about Dobsonians, they've brought a lot of new people into our hobby, for which we should be grateful.

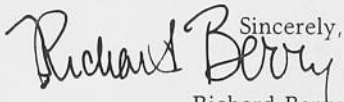
As for the telescope industry, the last two years have been miserable. We thought the recession had hurt telescope sales, but our survey says that people spent their discretionary income on a home computer instead of a telescope. Most telescope sales represent a bargain struck between the buyer and the rest of the family; telescopes tend to be a "for me" purchase, but a computer is "for all of us." Curiously enough, the telescope builders I've talked to seem to have become more engaged in their hobby as a result of computers, but skipped building a telescope or two and learned BASIC.

As a result of computers and the recession, there's been a shakeout of telescope dealers and manufacturers, probably not over yet. If you remember the big flap back in TM#11 about a firm that took the money and went out of business, keep in mind it could happen again. An excellent indicator of a company's health is its ad budget — keep track of that on a month to month basis and you'll know who's got good cash flow and who doesn't.

But none of the present trends are going to continue forever. The economy will do its thing; computers will saturate the market; people will get interested in fancy optical systems again; and somebody presumably will write a brilliant treatise on telescope optical design that will let us all design our own optical systems. TM will continue to reflect what's going on in our hobby, and, I hope, most readers will continue to be happy with what we have to offer.

A final note: As of March 15, 1984, the price of a year's subscription to TM goes up to $12 per year ($14 foreign). Since we like to be fair to our subscribers, we're telling you so you can renew or extend your subscription at $10 per year ($12 foreign). You can use the form on the back page, a photocopy of it, or a reasonable facsimile (whatever that means). If you want to order back issues — especially if you want quite a few — it would be a good idea to order them before their price goes up, too. Non-US subscribers must pay in US funds.

Sincerely,



Richard Berry

and coma. However, the size of the coma blur is about half that of an equivalent paraboloid. Thus an f/3.5 Schmidt-Newtonian (i.e., one with spherical primary) has the coma of an f/5 Newtonian, which is (in addition to a closed tube and freedom from spider supports) what makes these systems attractive for deep-sky astrophotography, while keeping the cost at an absolute minimum.

Mladen Vranjican, M.D.
63-141 Alderton St.
Rego Park, NY 11374

— Thanks for pointing this out; a number of people brought up the point. While recognizing what has now become common usage, I can't help but feel a bit sorry for Wright. Frankly, I think he doesn't get enough credit. By analogy to the application of the name Schmidt to virtually any system with a fourth-order correcting plate when Schmidt invented only the Schmidt Camera, the term "Wright" or "modified Wright" should apply to systems other than the telescope described by Wright (which Wright himself called the "short" telescope). If the application of Schmidt's moniker were equally closely delimited to the exact system he first described, then "Schmidt-Cassegrain" and "Schmidt-Newtonian," as we now use them, are equally incorrect.

No Dumb-Dobs!

Dear Richard Berry / I have enjoyed TM ever since it started. Contrary to criticism from Ray Reiffer in TM#19's "Letters," concerning there being too much about Dobsonians, I feel that every article you've published is useful to someone. And there is no such thing as a "dumb-Dob" — they're great telescopes. I say BRAVO to all those who have built them, especially the ones who have ground their own mirrors.

Walter R. Coggan
5407 5th Ave. N.E
Seattle, WA 98105

P.S. I have a Yashica twin lens reflex camera (several years old) which takes 127 film. I have discovered that it is an excellent camera for astrophotography, mainly for general sky views. However, the only films available are Verichrome and slow-speed color (from Kodak). If you or a reader know of any make of film that is 200 to 400 ASA and comes in 127 size, I would appreciate hearing.

Mirror Testing Woes

Dear Richard / In attempting to test my mirrors, I have tried as many different test methods as possible. In doing this, I have found a discrepancy between the Foucault test with Everest's pin method and the more frequently used zonal mask technique which I don't understand. The pin method always shows 25% to 35% greater correction than the test applied with the zonal mask. Recently I constructed a caustic tester and have found that there is better agreement between it and the method of the zonal mask. My mirror is a 12" f/8.

Discovering such a problem makes me wonder that authors tend to be (and have always tended to be) more optimistic than is warranted. With the large fast optics now coming into vogue, more needs to be said about how these "1/20-wave" optics are certified. Meanwhile, I would appreciate any ideas from you or your readers concerning this discrepancy.

Barry Levin
324 Sackett Street
Brooklyn, NY 11231

— Has anyone else tried testing a mirror with a variety of techniques? Did you get the same results from the different tests? Are there fundamental flaws or faulty assumptions in the pin test? Is Mr. Levin likely to be making an obvious error in his test procedures?

Automatic Guiding

Dear Richard / In TM#18, John Izzo asked for information on automatic guiding systems. There is an excellent article on "Autoguiders and Acquisition Systems for Optical Telescopes" by Dr. John V. Jelley in the *Quarterly Journal of the Royal Astronomical Society*, Vol. 21, pages 14-31. This survey paper by an astronomer at the Royal Greenwich Observatory covers all types of autoguiders, and contains some 61 references to the literature on this subject.

Russell M. Genet
Fairborn Observatory
1247 Folk Road
Fairborn, OH 45324

Info Needed!

Dear Sir / Recently I purchased a second generation image intensifier tube (Varo's 3603-1 MCP). I was wondering whether you or any TM readers would know of any good sources of information on getting these to work, as I have found it difficult.

Nicholas Bean
66 The Boulevard
North Balwyn, 3104
Melbourne, Australia

Good Guys

Dear Richard / In the past few years I've heard a lot of horror stories about the telescope and accessory market. And I have no reason to doubt these stories. I also believe the time has come for testing of astronomical instruments and major accessories. This can only be done by the major magazines as it would be expensive and time consuming. However, I think you both owe it to your readerships.

The largest single problem facing the amateur astronomer (with the possible exception of lack of available funds to properly deal with aperture fever) is the lack of information on what to buy. I am beginning, finally, to think I have a fairly good feel for the subject, but it has taken several thousand dollars of trial-and-error investments to get here. If consumer testing were available, I'm sure I would not have made some of the mistakes I did make.

Sure, testing might harm some marginal manufacturers. But marginal firms *should* fold if the quality isn't there. On the other hand, the firms who put out quality equipment will benefit. I don't think we should support struggling firms unless they are putting out quality equipment. If the quality is there, then assuming the price isn't too outrageous, we should support them, hopefully by buying their products (or perhaps in the case of both magazines, by providing truthful testing and affordable advertising space).

Since I started out talking about horror stories, let me also say some things I've not seen in print anywhere. I'm not sure the world is ready for this, but there *are* some "good guys" out there. I've done business with them, I own their products, and I feel others should know that they *are* good guys, not just purchasers of advertising space.

I've thought about it a lot, and the answer is the same, Meade Instruments is at the top of my list. The quality is there in spades, and the service is instantaneous and courteous. The people are friendly, courteous, and knowledgeable. I'm a customer for life. But wait! There are more good guys! And there is a tie for second place (and second place in this case is very close to first). And it's a four way tie!

Al Nagler/TeleVue Optics: This man has definitely changed my view of eyepieces. All that has been said about Al's eyepieces is true. And he is willing to answer your questions, too. Somehow it makes the money easier to part with. The service, again, is both quick and courteous, and the quality? As far as I'm concerned, the TeleVue Plossls, Naglers, and Wide Fields are the standard by which all others should be judged.

Lumicon: Somewhat specialized, but Jack Marling and Mike Healy have been *very* helpful to me when I needed information, and their filters are superb!

University Optics and Jan Seyfried offer good quality, fast service, and again, are friendly, helpful, and willing to take the time to explain something or answer questions.

Sadly, I've yet to buy anything from VernonScope, but hopefully I will yet. Don Yeier is another "good guy" who will help you out or answer your questions, even without getting a sale. And I *know* the Brandons are quality, even though I don't yet own one (I've used them).

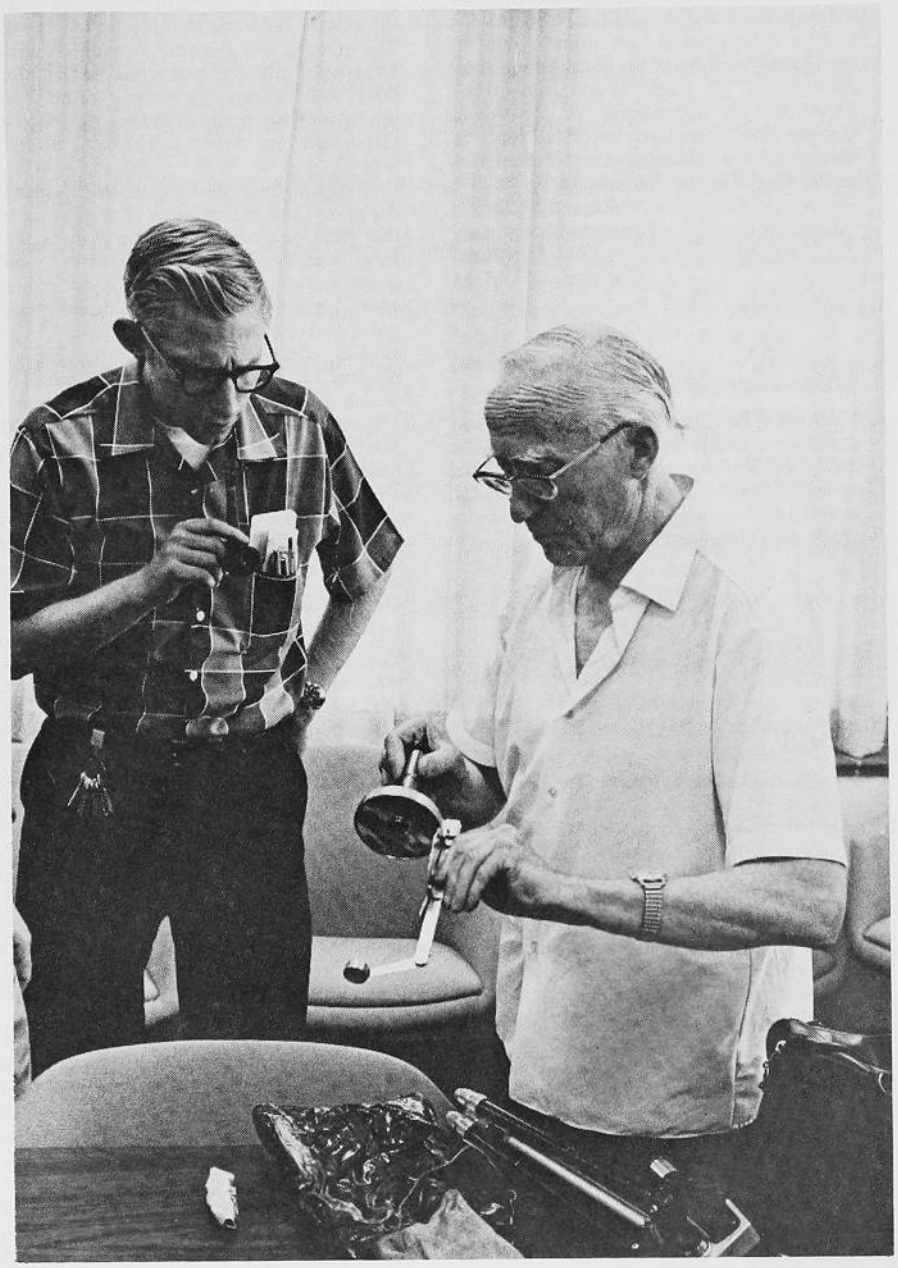
That covers second place. Honorable mentions go to Orion, Willmann-Bell, Telescopics, and Coulter Optics. Orion and Willmann-Bell I commend for very fast, courteous service; Telescopics for exceptional quality; and Coulter for reasonably priced, quality optics (Coulter's Odyssey telescopes brought complete, large aperture telescopes within the reach of amateurs).

I know this is a relatively huge letter for inclusion in your Letters to the Editor, but I hope you can print it anyway — not for me but for the "good guys." They really are, you know. . . .

Jan M. Owen
9007 W. Clarendon Ave.
Phoenix, AZ 85037

— It's nice to hear from somebody so positive about good guys. I usually get to hear only complaints. ■

A "Twitcher" Telescope



What in heaven's name is a "Twitcher"?

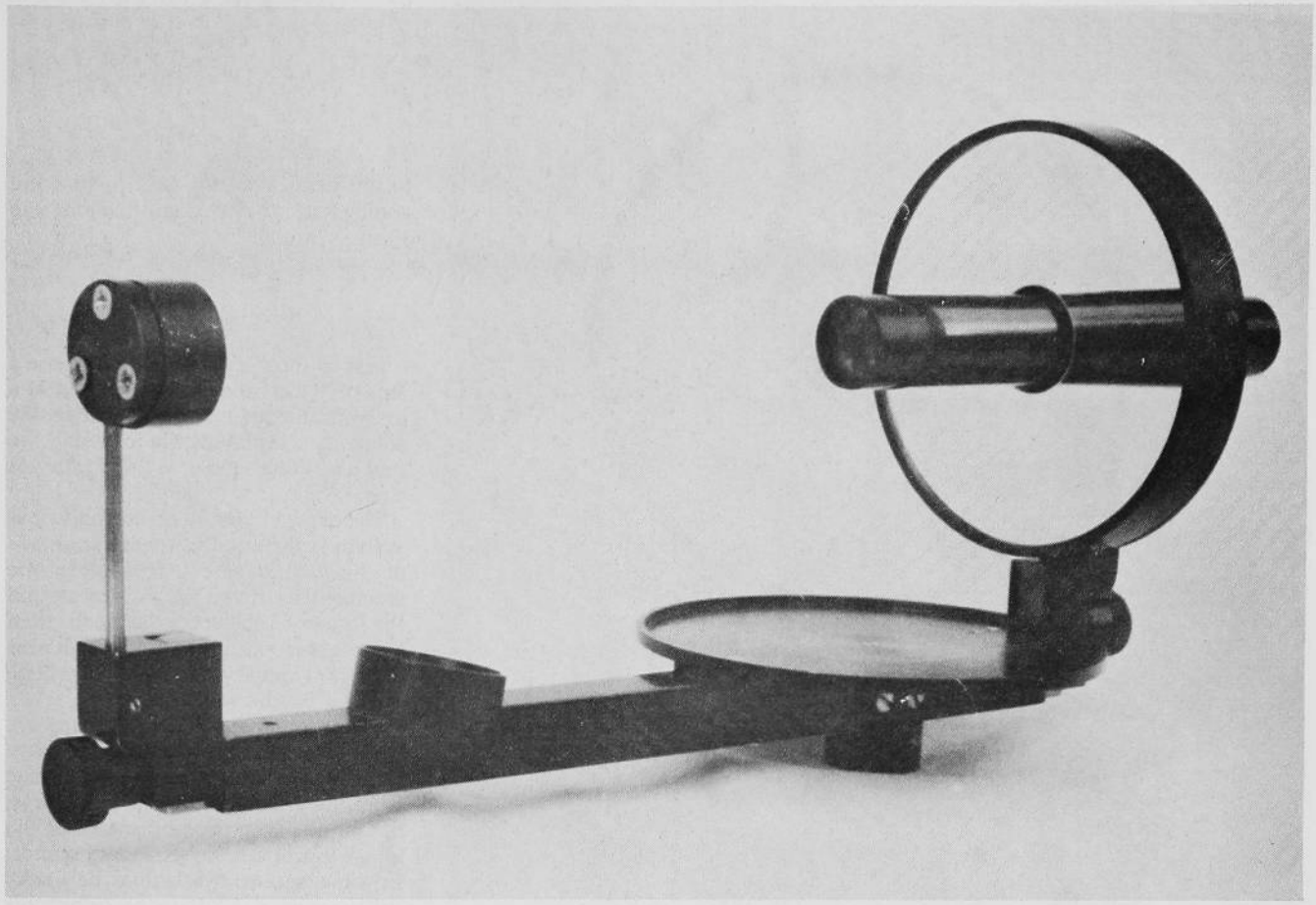
According to the dictionary, "twitch" means "to move a part of the body with a jerk" — but of course you still don't see what it has to do with a telescope.

Well, it's actually a term I've adopted to describe the reaction of people on seeing this telescope for the first time — a sudden twitch of desire to hold and look through it. Since 1962, the telescope has "twitched" numerous groups at star parties, conventions, meetings, and classes throughout the country.

And how does this all come about?

In the December 1947 issue of the *Scientific American*, in Unk Ingalls' "Telescopics" column, there was an article by Horace Dall on a pocket Dall-Kirkham 3¼" folding telescope he had built and was using. The design used an erecting lens in the optical train, and this not only made a tube unnecessary, but it also allowed one to use the telescope for terrestrial observation. Dall described how, a few years previously, he used the telescope to watch dog-fights between English and German planes in the skies above him — in fact one overzealous air raid warden had him arrested as a spy! Complete plans for the optics and pictures of its construction gave the reader lots of ideas on how to build one for himself.

In the middle 1950s, while I was working at the Optical Research Laboratories at Boston University, our shop foreman, George Random, and I decided to make the mirrors for the system and ultimately assemble a similar telescope. Some of the mechanical parts were made at this time, but on leaving the shops in 1957, I was forced to put the project aside because I lacked machining facilities. Upon moving to St. Louis in 1960 to



work on optics for the McDonnell space program, machine facilities were once again available to me — so the telescope was finally assembled.

One of the delays was finding a suitable erecting lens. I tried combinations of war surplus triplets and achromatic lenses, but they gave poor performance. It wasn't until I finally received a gift from a friend of a Perkin-Elmer triplet that it really worked right.

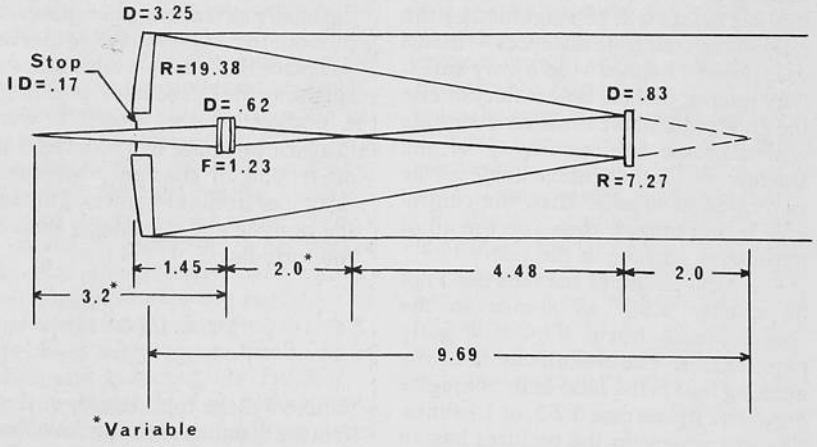
I think the telescope's most important feature is that despite its cuteness, it's not a toy. It actually gives a fine 40-power view and will show the rings of Saturn, but I can carry it in the inside pocket of my jacket! I also take it on vacations for terrestrial viewing — such as the bottom of the Grand Canyon.

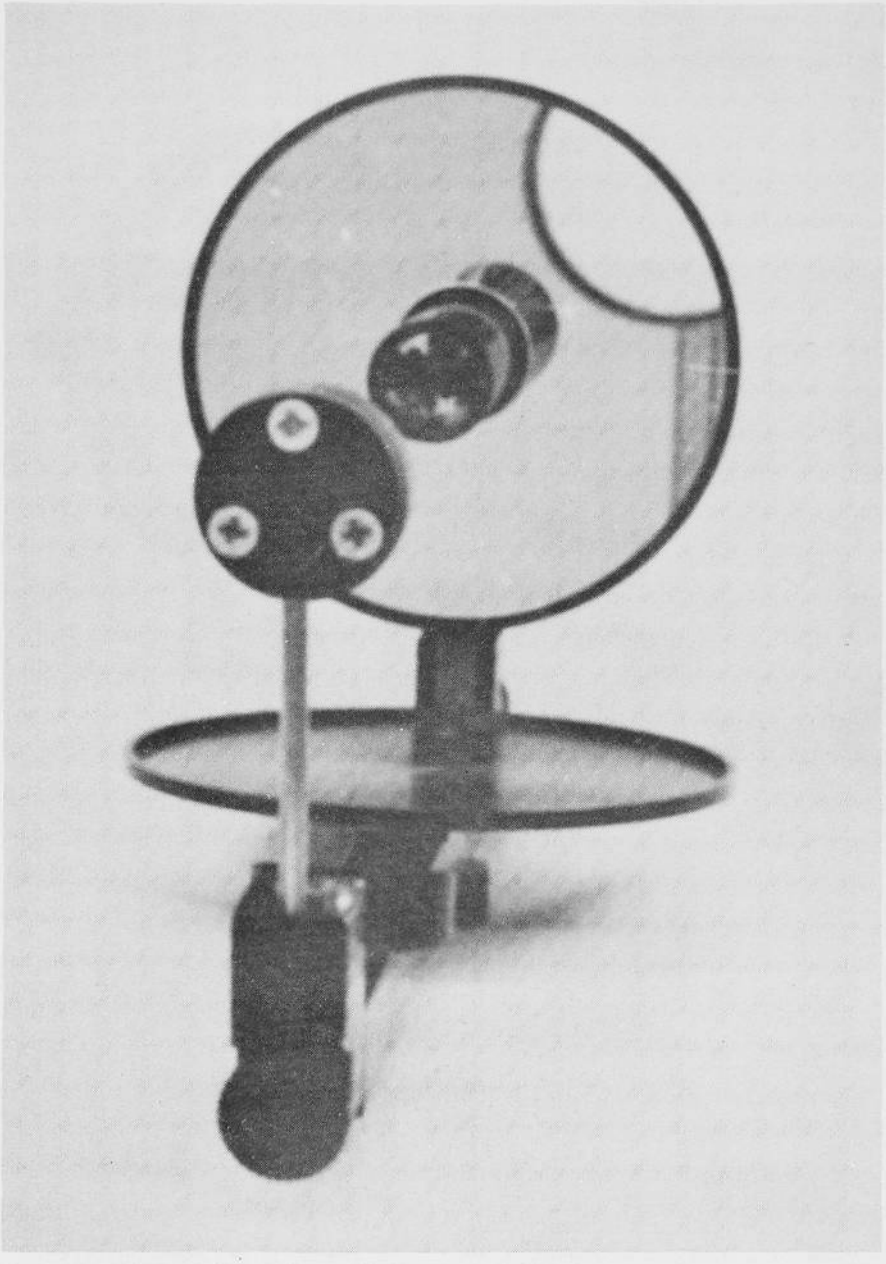
Many people have asked me where they can buy such an instrument, but my reply is always the same: they are not available on the market. You must make your own! Despite this, I don't recommend the instrument for the man-on-the-street. The mirrors are too exposed, and it takes a knowledgeable optics type to keep them in alignment; however, for those of you TM readers who wish to tackle a project of this kind, the parameters for the system are shown in the accompanying diagrams. One shows the optics spacings and curvatures of the optics; the other shows a null test at conjugate locations for testing the ellipsoidal primary.

The secondary mirror has a spherical shape and is made by testing with interference fringes in monochromatic light against a concave test plate until straight fringes are seen between the two.

Note that in Dall's instrument, the conjugates for the erecting lens are variable. In their mean position, they yield an f/10.7 system. By shifting the lens toward and away from the secondary, the telescope varies from an f/7.5 to f/18! My instrument focal ratio is fixed at f/13.

The ellipsoid on the primary can be tested at its elliptical conjugates of 10.35″ and 152.4″ as shown. The movement of the inner conjugate causes large changes in the second conjugate, so in setting up the test it is easier, in my estimation, to set the distant conjugate at 152.4″ and shift the inner one,





containing the pinhole, until one obtains the pinhole image at the distant conjugate position. Note that the pinhole image will be magnified by the ratio of the conjugate distances — in this case about 12 times — so a very small, very intense pinhole is necessary or else the enlarged pinhole at the far conjugate will decrease the sensitivity of the shadow test. If the pinhole holder is the same size or smaller than the central hole in the mirror, then you see all of the mirror surface in the test.

The focal length of the lens need not be exactly 1.23″ as shown in the specifications, but it should be fairly close to this. The magnification of the erecting lens is the ratio of its conjugate distances, in this case 3.2/2, or 1.6 times. The instrument in the pictures has an erecting lens that gives a magnification of 1.85 times.

It may be that the worker will want to know the focal length of the lens, especially as war surplus optics seldom turn out to be what they are marked. If you place the lens on a table at the same height as the lens center, and then put a pinhole at this possible working distance, an image will be formed on the other side of the lens. Measure the distances from the center of the lens to the pinhole and the image, then apply the formula:

$$1/f = 1/d + 1/d'$$

where f is the focal length of the lens, d is the distance of the pinhole from the lens, and d′ the distance from the lens to the image. If you want to find the conjugates for any magnification, use these formulae:

$$d = (1+(1/M)) \times F$$
$$d' = (M+1) \times F$$

Just to show by example: Suppose a lens of 1.118″ focus is to be used at a magnification of 1.5 times, what are the conjugates? Applying the formulae, we find d = 1.863″ and d′ = 2.795″ for this lens.

The other important object in the lens system is the stop, in reality an image of the secondary cell formed by the erecting lens. If you place a stop around the image of the secondary cell, then only light from the secondary will pass through it and sky flooding light will be blocked by the stop.

The location and size of this stop are easily found using the formulae we have just discussed. Determine the distance from the erector to the internal focus, d, and add it to the p′ distance of the image in front of the secondary mirror. In the diagram, this would be 6.48″. With a lens of 1.23″ focus, apply this formula:

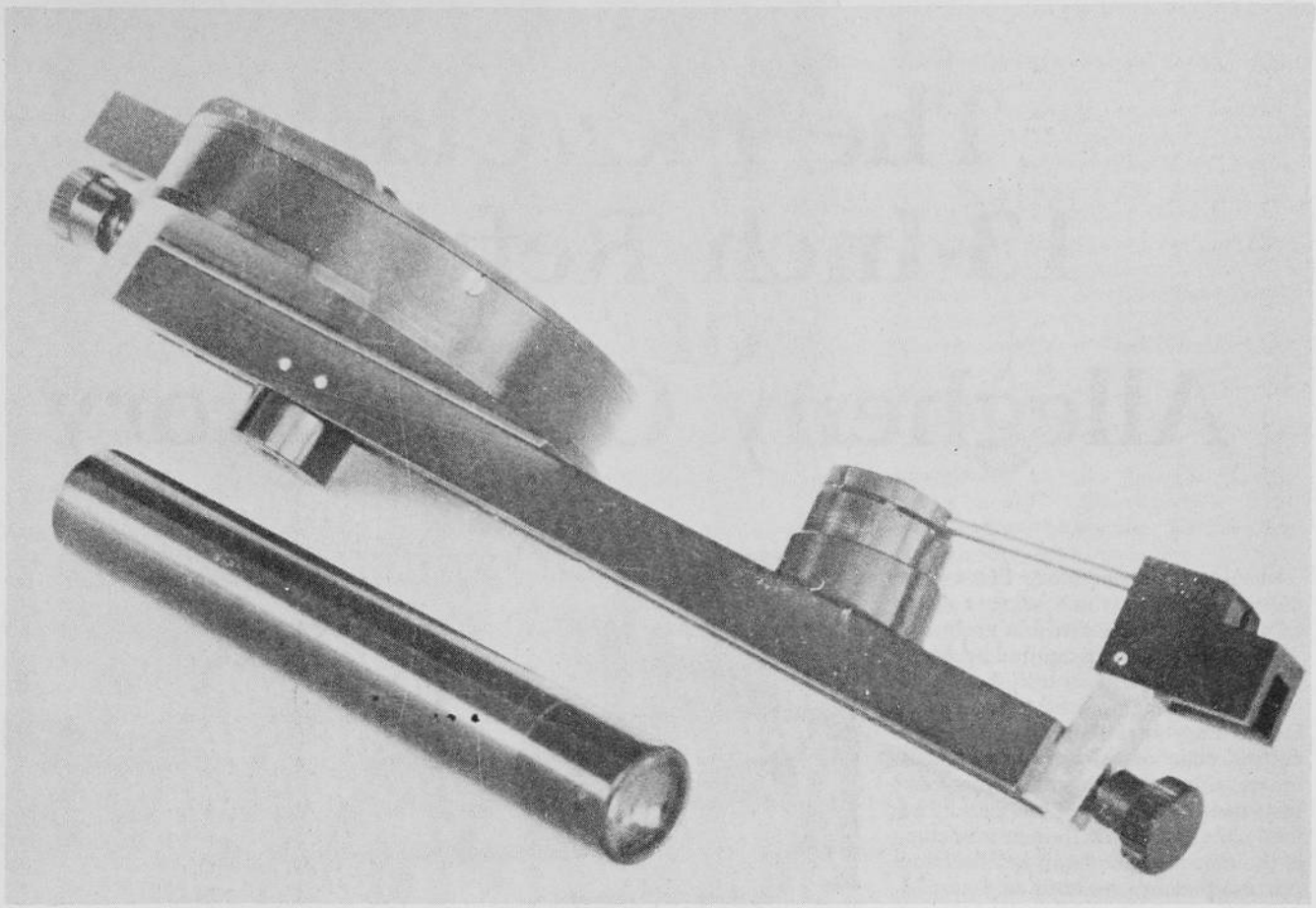
$$1/f - 1/d = 1/d'$$

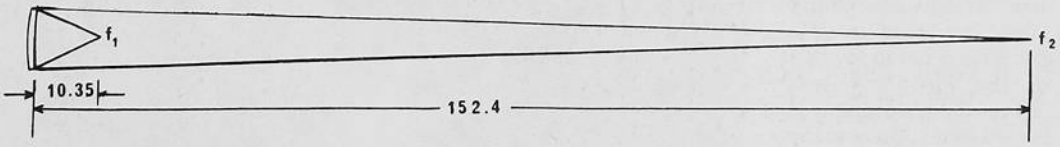
and obtain a distance of 1.518″.

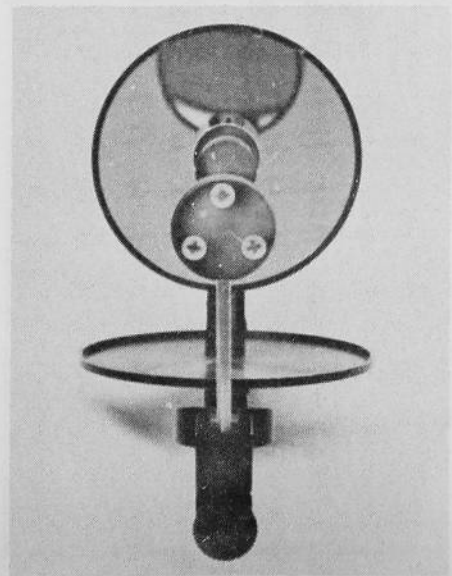
But wait, the plans show a distance of 1.45″! The difference is that Dall made a compromise size as he was moving his lens to vary the overall focal length of the system from f/7.5 to f/18. If we fix the position of the lens for an f/10.7 cone, then the 1.518″ distance would be correct. As for the size of the opening in the stop, it is the reduction ratio of the conjugates, 1.450/6.480, or 0.2238. Multiply by the secondary size, 0.83″, to get 0.186″. Once again you'll note differences due to the moving lens.

For the eyepiece in this telescope, a symmetrical Plossl is recommended and this will give long and comfortable eye relief, making it possible to use spectacles when viewing. The field of my pocket instrument is about 1°, and is somewhat restricted by the size of the field lens in the edged-down orthoscopic eyepiece. At f/13, the system could probably be made to deliver a little bit more by redesigning the eyepiece assembly at the back of the unit.

In the January 1962 *Sky and Telescope*, page 48, Dall presented plans for a 6″ Dall-Kirkham with an erecting lens (a







telescope to fit a raincoat pocket), and in the February 1962 issue, plans for using a Maksutov design. In the January 1962 issue, you'll find the formulae for calculating the undercorrection of the primary of the Dall-Kirkham and the location of the two null test conjugates.

The telescope's mechanical construction is left up to the reader. It will vary according to your capability and shop equipment. For best results, I suspect precision machine work is required on the mounting parts, but I hesitate to state that categorically. One should never underestimate the ingenuity of the amateur who, more often than not, finds clever ways around problems of making and mounting his optics.

For my "twitcher," I made everything out of aluminum except the pivot pieces for the optics — which are brass — and the upright holding the secondary mirror which is stainless steel. All aluminum parts are black anodized for appearance.

If I were to make any changes, I'd replace the cap screws holding the mirrors upright with a quicker means of assembly. Spring clips might be able to do the same task. It would be helpful to have some means of holding the mirror cells in their receptacles in the base when the unit is collapsed.

I don't recommend this as an instrument for T. C. Mits, "the average man on the street"; it takes careful handling to keep the optics clean and big doses of T.L.C. to keep it in alignment. But don't let that discourage you: this is an instrument for TMs!

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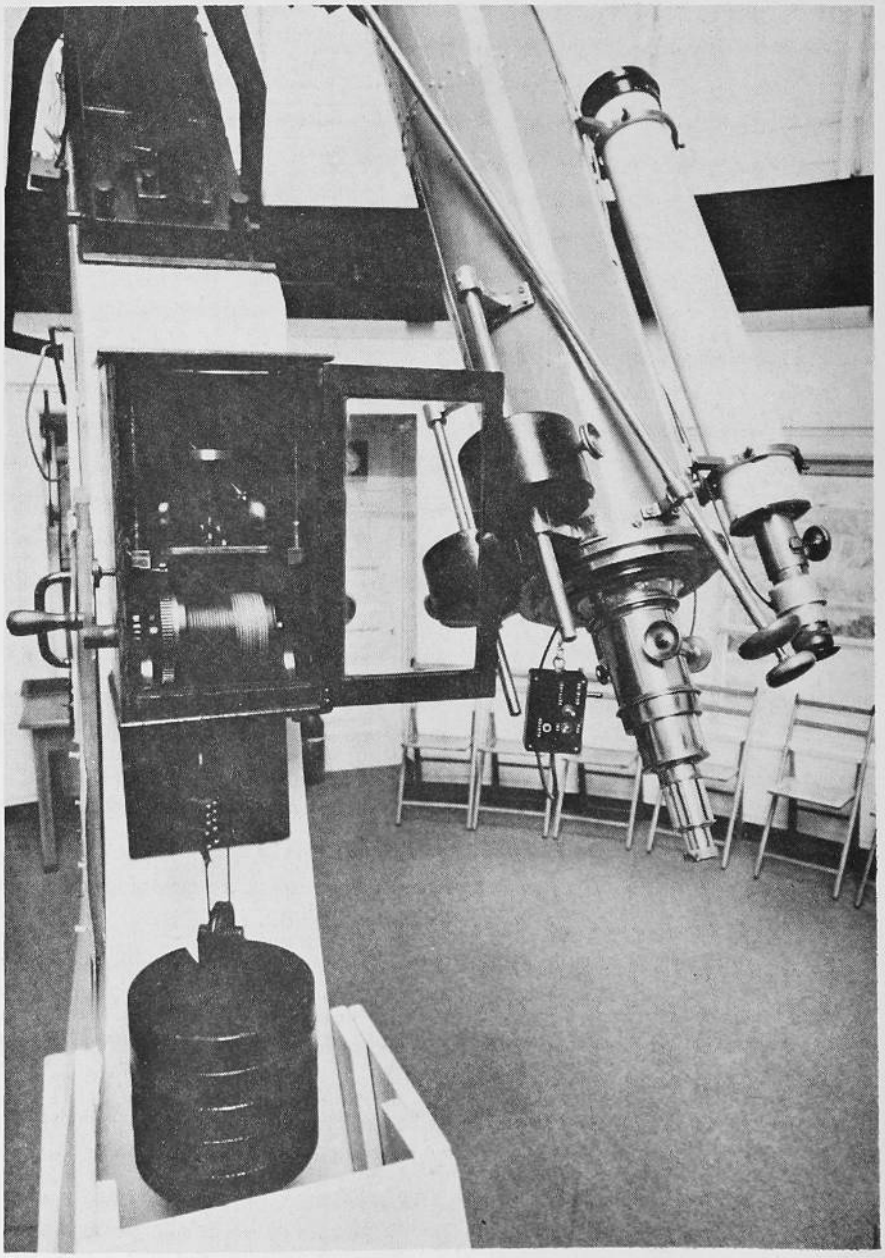
The Fitz/Clark 13-Inch Refractor of Allegheny Observatory

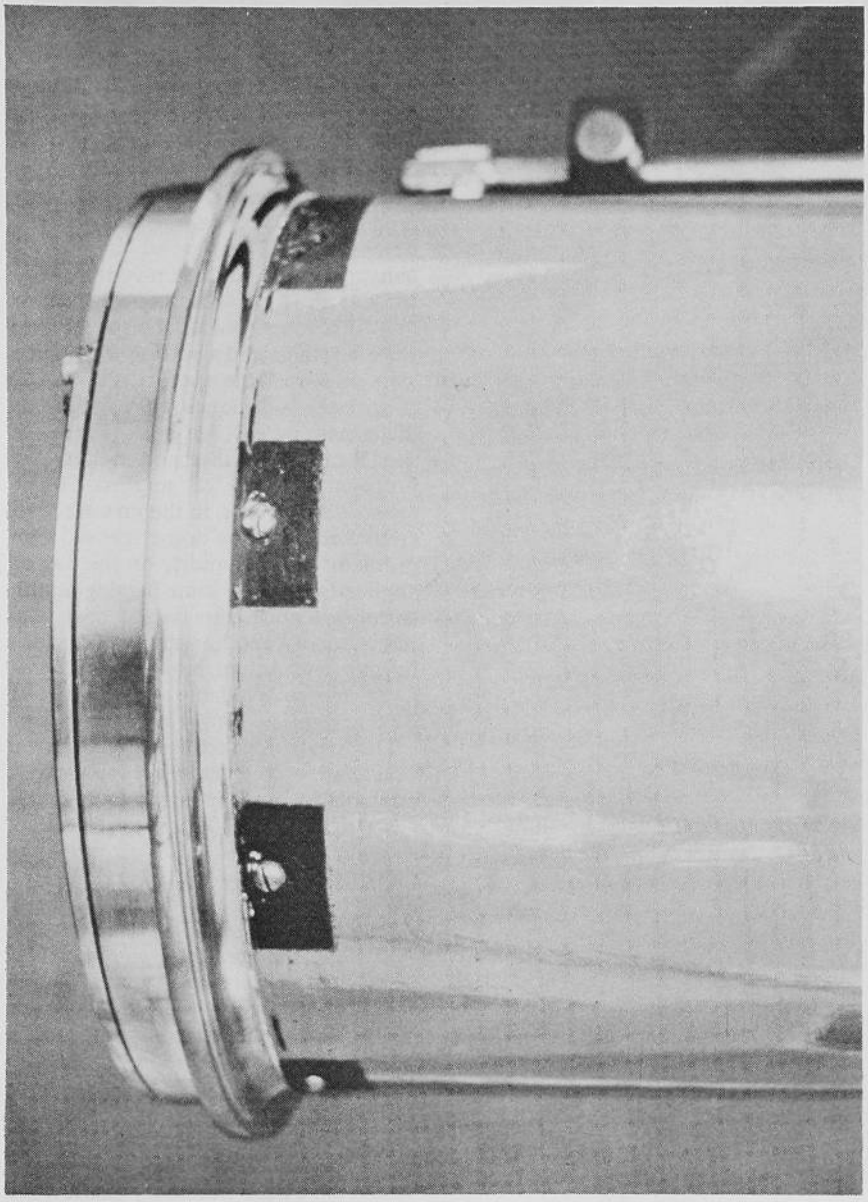
Imagine an observatory that's part museum, a place which inspires every astronomer or visitor with a profound sense of scientific and cultural heritage. One place where you'll find this inspiring medicine is the Allegheny Observatory in Pittsburgh. Here the cutting edge of astrometric research meets an instrument born of the great instrument makers of the past. The latter, the Fitz/Clark 13-inch refractor, is the object of an ongoing restorative process that honors both science and art.

It was under the patient and encouraging eye of Dr. George Gatewood, director of Allegheny Observatory, that my part in this renovation began. This is not to say that the rebirth of the Fitz/Clark was phoenix-like, or that the telescope was born again of its own ashes. Quite to the contrary, this instrument survives in remarkable shape, with minor changes that have been made usually accountable to time or relocation.

There is one material, however, common to scientific instruments and works of art from the period when the Fitz/Clark was built. This material — brass — adorns the remarkable refractor. This beautiful gold-like metal, so easily shaped and machined, adds a distinctive and aesthetic quality woefully absent in today's antiseptic stainless steel, aluminum, and exotic titanium alloys. But Fitz went a step further by blending both rose and yellow brass pieces side by side, alternating materials, thus creating a functional work of art. The effect of this was probably missed by the hard-core



Here the finished tail piece is shown next to the gravity drive mechanism. The brass diagonal shaft on the tube is the Dec. slow-motion control. The original mounting, circa 1860, with sector arms encircling the pier.



The finished objective cell with new brass counterweight shaft at the top. Note the brass bolts securing the cell to the steel tube.

A close-up view of the tung oil coated tailpiece.

science types over the years.

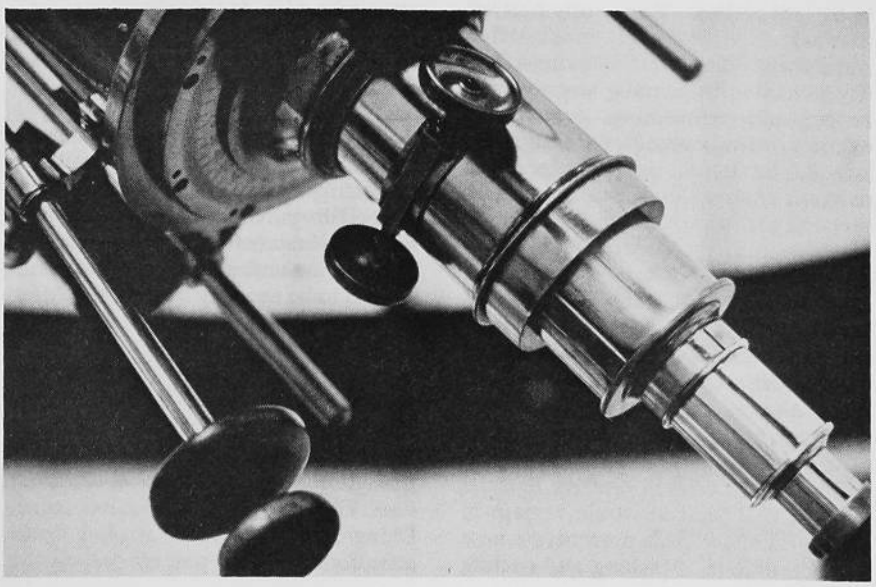
When I first saw the 13-inch, it was housed in its "new" home. For "new," read 1912 — the refractor had been operational in the original Allegheny Observatory at the time when Abraham Lincoln was president. Its tapered metal tube was painted blue, and much of that brass adornment painted black. Some pieces had been added, however, including the metal tube. The original wooden one had long since been removed from service. The finder, electric clutch for the gravity drive, and R.A. slow-motion controls were all decidedly 20th century.

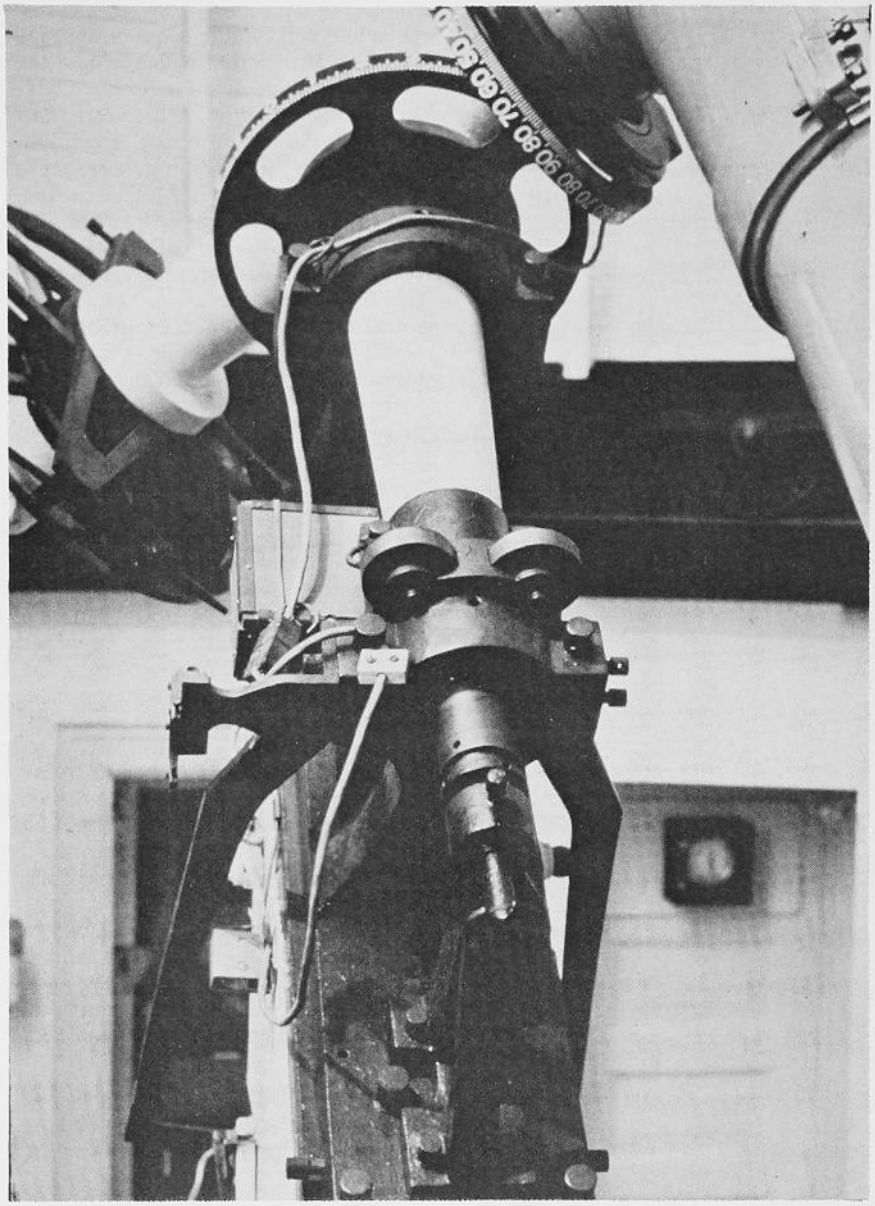
Restoration began by removing surface tarnish with conventional Brasso. This allowed us to inspect the brass pieces and determine how much more work would be required. Unpainted brass surfaces included the objective cell, cradle cross straps, tail piece, main counterweights and the silver inlaid declination circle. After careful examination, we found most surfaces, although in good condition, were pitted. Some pits and marks were obviously present in the original casting, but most had been caused by Pittsburgh's airborne pollutants.

We had to work carefully around the telescope's busy schedule. The 13-inch refractor is used almost nightly by the staff as well as the public. Visitors on tour can observe the heavens with this instrument, a tradition unique to Allegheny Observatory.

The tail piece was the first item removed. Enlisting the aid of assistant astronomer George Fennell, it was taken to the Observatory's fully equipped machine shop. There, after disassembly, each piece was polished using red jeweler's rouge and a polishing wheel. Little else could be done because of the numeric engraving around its innerfacing circumference. The red rouge, designated for brass, copper, and gold, brought a very high mirror-like shine to the tail piece, including various knobs and wheels. Some pitting remained in the vicinity of the graduation, but it was determined that its removal would disturb the demarcation.

The next problem was how to maintain this high lustrous shine. Having had some experience with such matters, I advocate the use of tung oil over the commercially available plastic





The original mounting of the telescope, circa 1860. To the far left is the one remaining original declination circle. This brass circle is silver inlaid and accurate to 20 arc-seconds.

base varnishes. Tung oil neither discolors with age, nor dries translucent. Therefore, following a final dry polishing to remove any residual rouge, and reassembly, we coated exterior brass surfaces with tung oil applied by hand, using fingers and palms. The streakless, coated piece was then left to dry in one of the many dust-free, humidity controlled rooms common to observatories or research facilities. A second coat was applied 24 hours later. Following re-installation of the tail piece, the next and far more challenging operation began — the restoration of the objective cell.

Not wanting to be remembered as "the one who damaged a 120-year-old and nearly priceless objective lens," I decided that the cell would remain in place and intact. This presented a new set of problems. Masking and sealing the cell against the dust I would be creating was necessary, as well as protecting it against loose brass filings — yes, filings. With all due apologies to antique dealers and collectors, removal of deep pits and marks with a fine file proved to be the only alternative. After all, Allegheny Observatory is a functioning research facility, not a museum, and so the go-ahead was given.

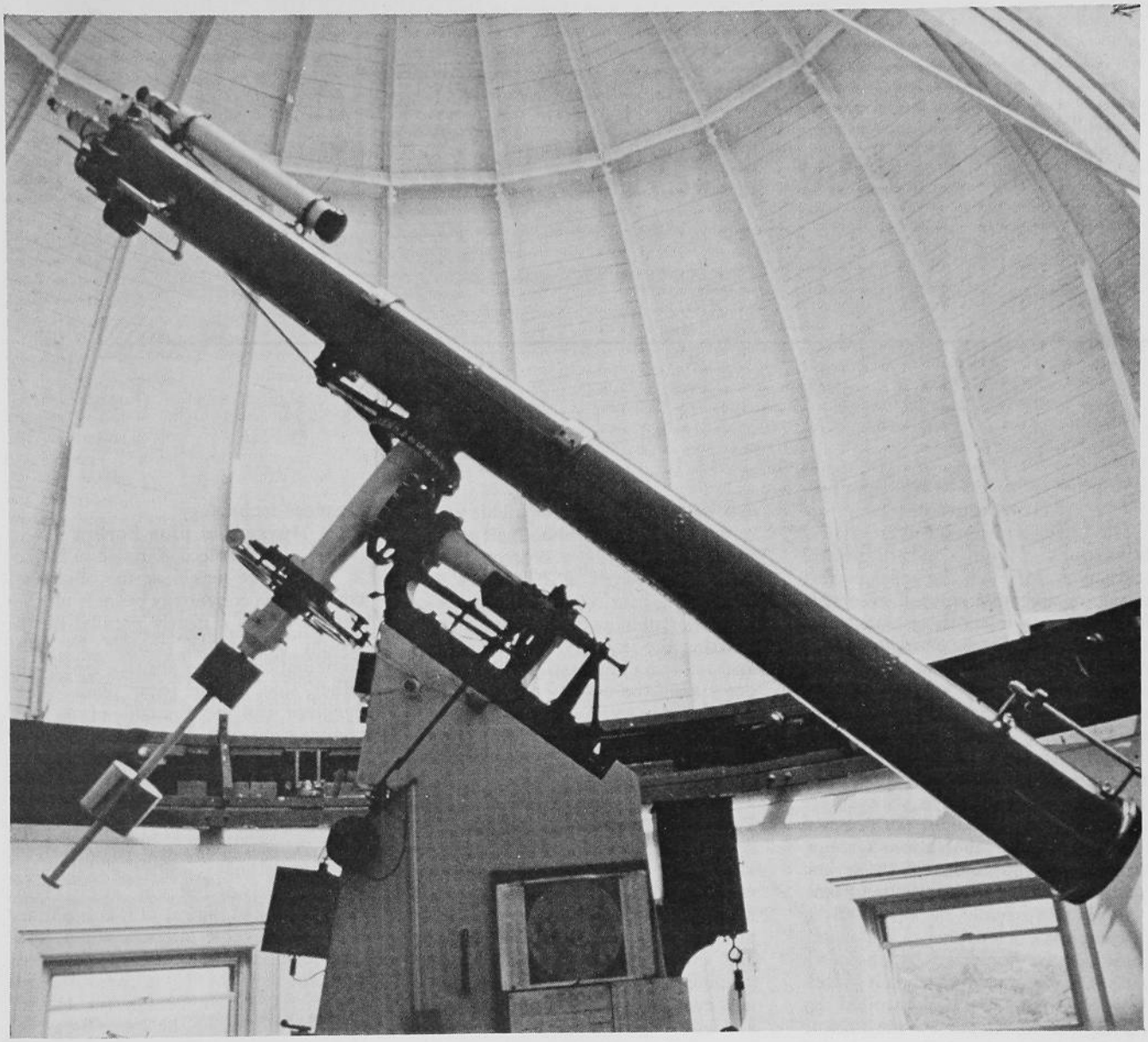
The exact shape of the cell was unchanged by careful use of rat-tail, triangle shaped, and fine flat cross-cut files. The operative word here is *fine*. Using single foward strokes with attention to detail, one by one all the surface pits were removed. Rat-tail files allowed curved and convoluted surfaces to be restored without alteration. This was followed by multiple sandings with emery cloth of medium and fine grit sizes — a step which should not be shortened or eliminated since care here creates an excellent base for final polishing. Any sanding marks left behind were removed by using polishing compound — fine grit for auto body work — and a buffing wheel prior to a final rouge polish. This was done with red rouge and a buffing wheel, this time on a variable speed drill.

Once the techniques were perfected, the remaining exposed brass was easily filed, sanded, polished and coated. The preservative tung oil applied to the telescope, however, in the uncontrolled environment of its dome, caused one problem: High humidity on the day of application caused some fogging on the surfaces; hence, the fogged coat was removed and another applied on a less humid day. Actual humidity percentages were not available at the time, but 50% or less is strongly recommended.

The next step required testing for brass and iron by gently scraping small amounts of built-up black paint from suspected pieces. The finer counterweights were assumed to be iron, but this left the uprights and shafts questionable. All proved to be brass, with yellow brass being used for the shafts and rose brass for the uprights. Using commercially available paint remover, no less than 3 separate coatings were needed to eliminate years of "convenience."

It is here that another glimpse into history occurred. Assuming that all these original parts were literally handmade, some identification marks would have been necessary to allow for fitting and refitting. I found these after the paint was removed. Apparently Fitz had stamped a number 1 and 2 on the uprights to distinguish them, and a corresponding numeral on each end of the counterweight shafts as well. Even the handmade bolts were not interchangeable and had to be heated for removal. These smaller pieces again were taken to the machine shop for filing and massage. After two coats with tung oil, each piece was back in the dome for reinstallation after forty-eight hours.

The only alterations made during this restoration were to the front counterweight set. Apparently sometime during the years, the original brass shaft was removed and replaced with one of iron — the motive for this is unknown. In the interest of art and to maintain continuity, the iron shaft remained in the machine shop, and a local firm was



The 13-inch, shown in the stowed position, awaiting measurements for a new stepping motor. Note the tapered steel tube.

commissioned to provide a new yellow brass shaft of the proper diameter. Following some careful drilling and tapping, new rose brass bolts of standard thread size were installed. The Fitz/Clark was nearing completion.

Hours spent in such close association with great works from the past gives a strong sense of respect and even love for artisans of Fitz's class — not only from a technical or mechanical aspect, but from a scientific one as well. Using this telescope on many occasions, this author was overwhelmed with images with fine contrast and excellent definition worthy of the skills of men such as Brashear, Fitz, and Clark.

It is also humbling to consider the "firsts" attributed to this particular instrument. Coming into use in 1860, used by the likes of Langley and Keeler for determining the temperatures of the Sun and Moon, or discovering the particular nature of Saturn's rings, are only some of the accomplishments of this telescope and observatory. Add to this that it remains the only telescope to have its lens stolen and held for ransom, and you'll understand why this telescope has the makings of more than a few lines in a book of history.

There will be a place in tomorrow for this Fitz/Clark as well. When finally completed with a new stepping motor to replace the gravity drive, a filar micrometer for double star measurement, and some new paint here and there, the next generation of techno-visitors can discover and rediscover the mysteries in the night skies above Pittsburgh.

Combined with its two Brashear companions — the 30-inch refractor, now with the Gatewood MAP* instrument, and the 31-inch reflector with its Mellon spectograph, both 70 years old — we see astronomy and history blending to make Allegheny Observatory both a research institution and an innovative kind of museum.

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*MAP (Multichannel Astrometric Photometer) is an invention of Dr. George Gatewood, developed at Allegheny Observatory to plot perturbations in star orbits for the purpose of extrasolar planetary discovery. This computer/electronic/fiber optic device has replaced the traditional photographic astrometry program of Allegheny Observatory.

A New Flat Field Eyepiece

Introduction

The eyepiece separates visual telescopes from photographic telescopes, for even the most perfect mirror or objective will fail miserably for visual use unless the eyepiece can accurately magnify the image formed by it. An eyepiece is subject to the same aberrations as any optical system: spherical aberration, coma, astigmatism, curvature of field, distortion and the chromatic aberrations, longitudinal color and lateral color. And, since an eyepiece works at large field angles like a camera lens, the field aberrations, coma, astigmatism, curvature of field, and lateral color are particularly important.

Coma can usually be corrected by proper choice of lens shapes, and lateral color can be corrected by choice of glasses, element powers, and air spaces. Astigmatism can be controlled by varying the lens shapes, but the intimate relation between astigmatism and curvature of field dictates the amount of astigmatism needed to flatten the field. Curvature of field is determined by the weighted sum of the powers of the individual lenses in the eyepiece plus a multiple of the astigmatism. This sum of powers weighted by refractive index is the Petzval sum. Eyepieces that consist of positive simple or doublet lenses such as the Huygenian, Plossl, and Erfle have a large Petzval sum and hence a large field curvature that must be balanced with astigmatism.

To compensate for this curvature and produce a flat field, large amounts of astigmatism must be designed into the eyepiece. Figure 1a is a plot of the sagittal (parallel to field angle) and tangential (perpendicular to field angle) focal positions for a Plossl eyepiece design (ref. 1). The large separation in the two focal positions is necessary to flatten the field; without this astigmatism the best focal plane would be curved to the left about half again as much as the sagittal curve, roughly 5% of the focal length at 25 degrees. The optical designer has a difficult choice between flattening the field and thereby blurring the image with astigmatism, and correcting astigmatism but defocusing the edge of the field. The choice made by the Plossl designer is about the optimum for producing the sharpest images in an eyepiece with a large Petzval sum.

A few modern designs such as the Fleischman (ref. 1) use a negative lens near the focal plane to reduce the power sum and reduce the need for compensatory astigmatism. The negative lens near the focal plane does little other than reduce the power sum, and the rest of the eyepiece often becomes complex. I have invented a new eyepiece consisting of two positive and one negative lens having a zero power sum, giving very good correction of all aberrations except distortion (ref. 2). The ability to correct aberrations results in part from the location of the negative lens well in front of the focal plane so that favorable "optical leverage" is obtained. The sagittal and tangential focal positions for an example of this triplet eyepiece are shown in figure 1b. The field is nearly flat with little astigmatism much like an anastigmatic photographic triplet.

In the remainder of this article some designs based on this triplet eyepiece concept that use common glasses and symmetrical lens shapes will be presented. I have not yet found a manufacturer (while I fancy myself an optical designer, I am no optician), but the simplicity of this new eyepiece should lend itself to construction and experimentation by amateur astronomers. So read on — and be the first one on your block to have the latest in eyepiece technology!

Huygenian plus Barlow

This new eyepiece is shown in figure 2. A negative lens near the objective converts the converging beam from the objective into a nearly parallel beam which is further imaged by the combination of two positive lenses on either side of the focal plane. The eyepiece can be thought of as the combination of a Barlow lens with a Huygenian eyepiece, and this is actually how I came upon the idea. A Huygenian eyepiece has positive longitudinal color, zero lateral color, and positive Petzval sum. A simple Barlow has negative longitudinal color, positive lateral color, and negative Petzval sum. The combination of Barlow plus Huygenian thus has positive lateral color as the most significant aberration not affected by lens shape. It is possible to overcorrect a Huygenian for lateral color by increasing the space between the lenses or by using a higher dispersion glass (e.g., flint) for the field lens.

The combination of overcorrected Huygenian plus simple Barlow is thus potentially corrected for chromatic aberrations with zero Petzval sum, so that the three lens shapes can be used to correct for spherical aberration, coma, and astigmatism.

After some trial and error I discovered that the combination of a negative lens with focal length −1, and two positive lenses of focal length 2, all of the same glass had zero chromatic aberrations if they were spaced by a distance of 2 negative to positive, and a distance of 4 positive to positive. The Petzval sum is 0 (−1 plus ½ plus ½), and the effective focal length is 1 unit. If the lenses were in contact, the combination would have zero power, so the focal properties of the triplet combination derive entirely from the spacing of the

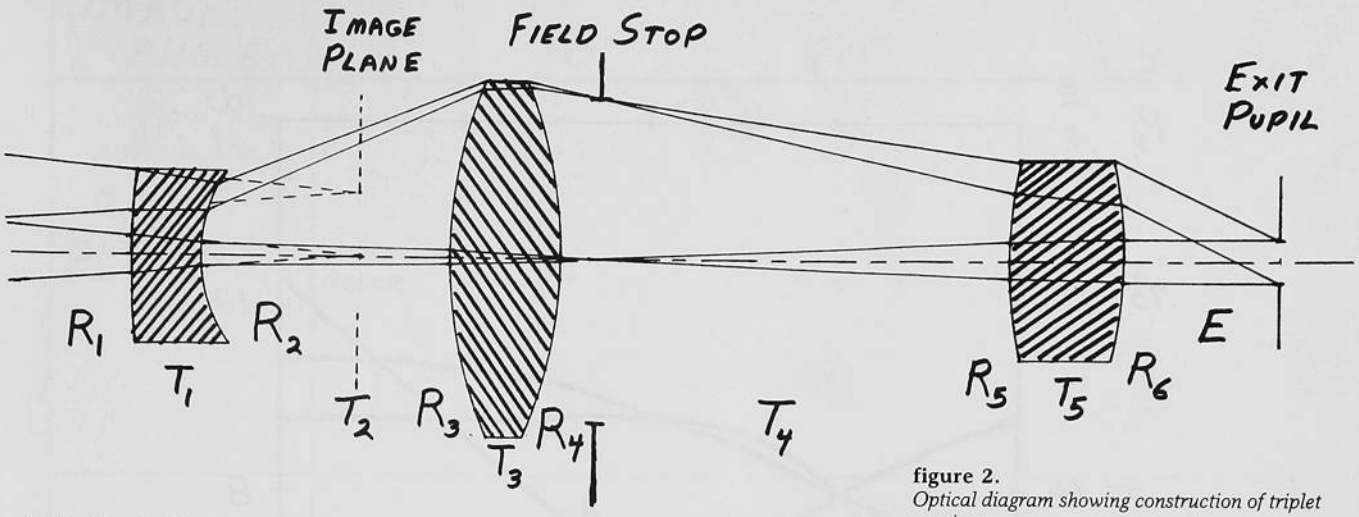


figure 2.
Optical diagram showing construction of triplet eyepiece.

individual lenses. This triplet configuration also has the bonus that the exit pupil is distance 1 from the final positive lens; this is a relatively large distance with respect to the focal length.

Further experimentation combined with some algebra showed that a whole family of triplet eyepieces exists, all using the same glass for the three lenses and all having a negative lens of focal length −1 separated a distance of 2 from the first positive lens. The total positive power +1 is divided between the two positive lenses, and the spacing between the positive lenses is varied to correct for chromatic aberrations. Mathematical details can be found in my article published in *Applied Optics* (ref. 2).

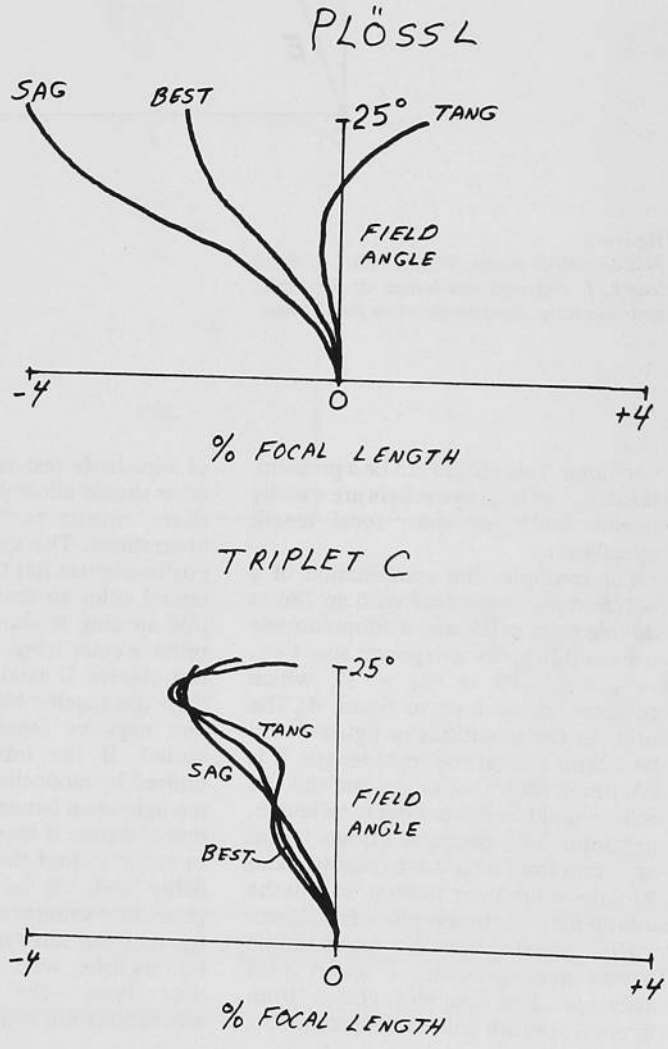
Using Miscellaneous Lenses

This family of triplet eyepieces can be used as the basis for experimentation using miscellaneous lenses you may have in your junk box. Figure 3 is a plot of critical separations and lens powers for this family of triplet eyepieces. It turns out to be convenient to express the parameters of this family in terms of the quantity e, the ratio of the exit pupil distance E to the focal length f.

Figure 3 is a plot of E, f, P3 and d *versus* e. The additional quantities P3 and d are the power of the second positive lens and the separation between the positive lenses. The focal length f3 of the second positive lens is 1/P3 and that of the first is 1/(1−P3).

The eyepiece is scaled to different focal lengths by multiplying all separations and focal lengths by a scaling factor. Since these distances are in units of −f1, when using existing lenses the scaling factor is −f1. When using figure 3 to identify suitable lenses, the desired f1 is −1/f times the eyepiece focal length, and the −f1 multiplies the other focal lengths. When the ratio of eye relief to focal length e becomes large, the resulting eyepiece becomes

figure 1.
Plot of sagittal focal position, tangential focal position, and best focal position relative to on-axis focus for (a) Plossl eyepiece, and (b) triplet eyepiece C.



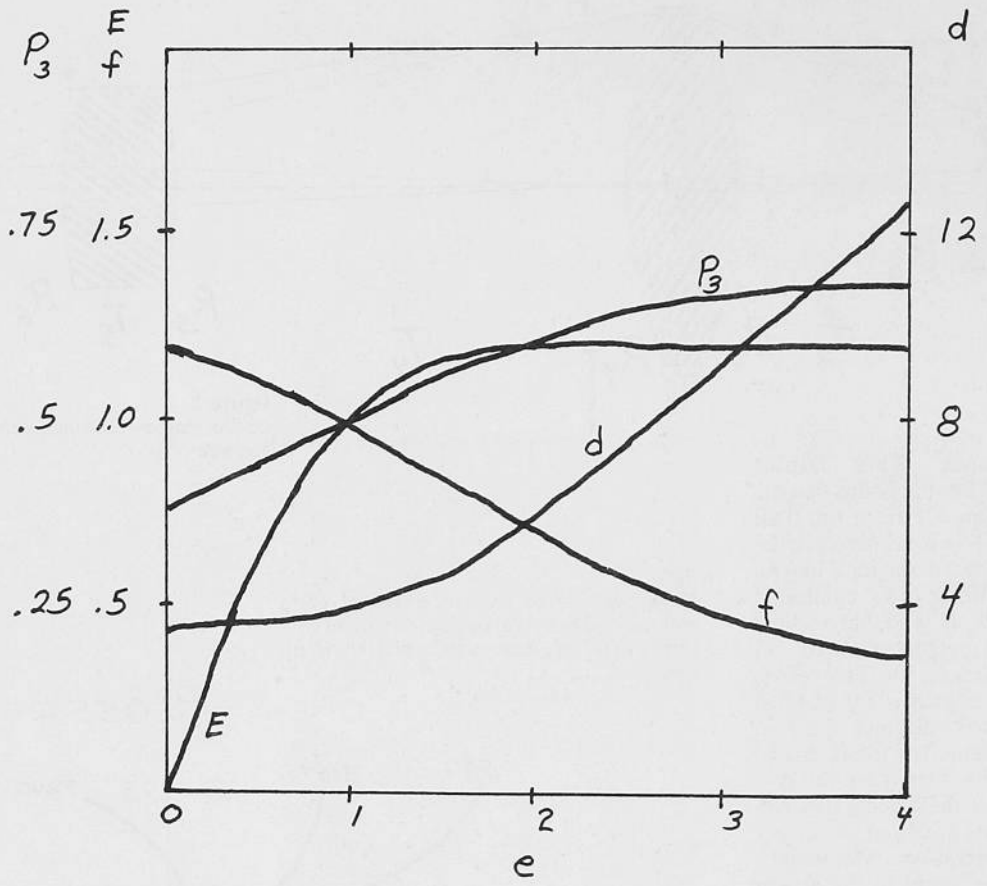


figure 3.
Plot of eyelens power, P3; eye relief, E; focal length, f; and lens separation, d; for triplet eyepieces using the same glass type for all lenses.

very long. This should not be a problem, however, as long eye reliefs are usually needed only for short focal length eyepieces.

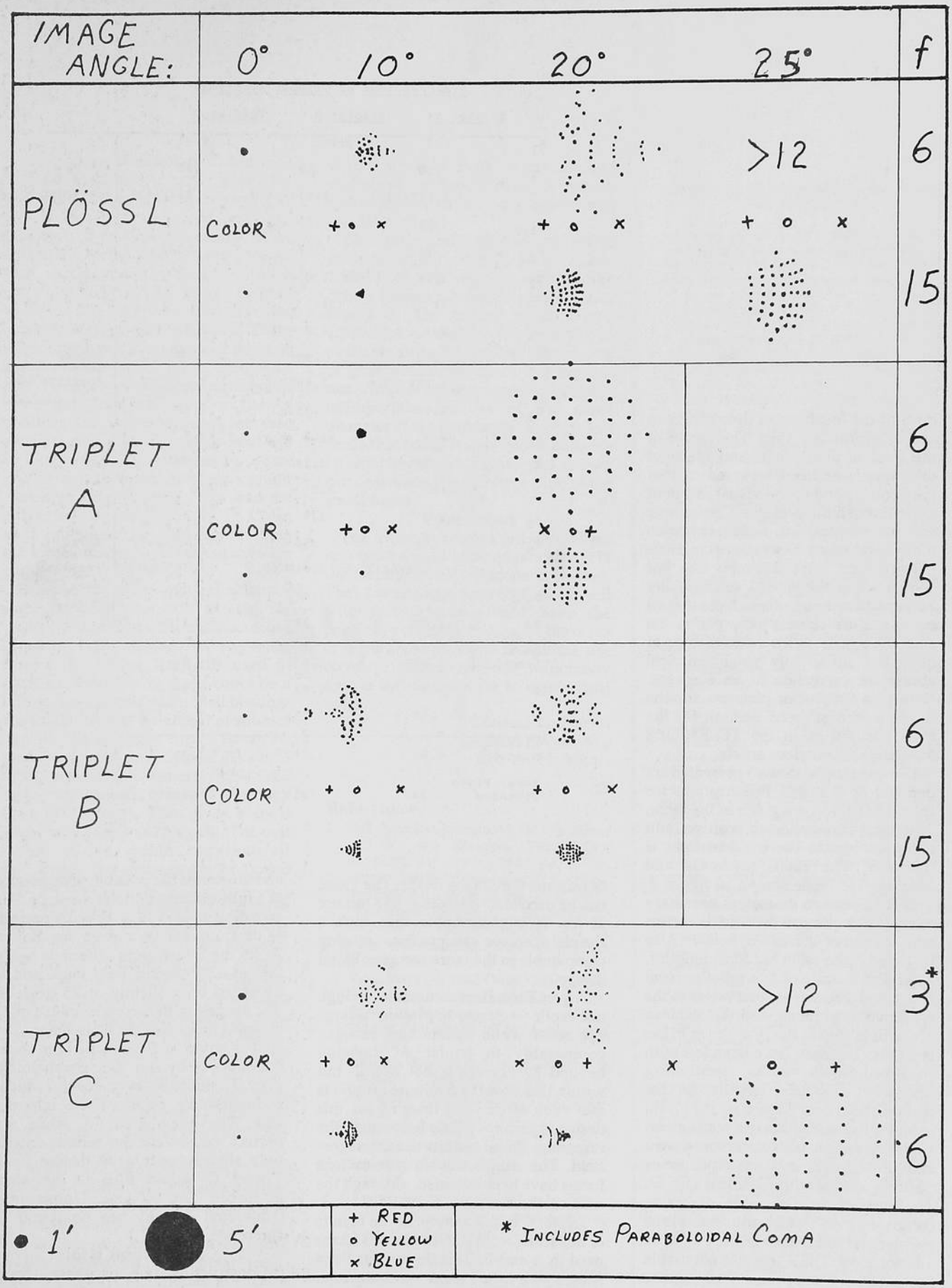
For example, the combination of a −12mm plano concave with an 18mm double convex (f3) and a 36mm double convex (f2), gives zero power sum ($-\frac{1}{12} + \frac{1}{18} + \frac{1}{36}$). P3 is $\frac{12}{18} = \frac{2}{3}$, which corresponds to e=3 in figure 3. The units of the quantities in figure 3 will be 12mm so that the focal length, f, is 0.5 times 12mm, or 6mm; and the eye relief should be e times the focal length, or 18mm. The spacing is 2 times 12mm or 24mm from negative to positive, and 9 (d) times 6mm, or 108mm, so that the total length of the eyepiece is 132mm.

Experimentation with a box of simple lenses may produce a fairly good eyepiece. The spacings gotten from figure 3 are thin lens values; some sort of adjustable test set up and trial and error should allow you to find spacings that minimize the chromatic aberrations. The spacing between the positive lenses has the largest effect on lateral color so that by adjustment of this spacing it should be possible to remove color fringes from the edges of test objects. If axial color is excessive, then the spacing between the positive and negative lenses should also be varied. If the image is excessively blurred by monochromatic aberrations, the individual lenses should be reversed one at a time if they are asymmetrical in order to find the best orientations. Selby (ref. 3) advocates a similar procedure using achromats in ATM #3. In any case, this type of triplet should be usable with large f/number objectives; the only eyepiece aberrations not reduced by increasing the f number of the objective are lateral color and distortion, and lateral color.

Designs Using Flint Glass

Another way to compensate for the chromatic aberration of the simple Barlow component is to use high dispersion or flint in the first positive lens. Figure 4 is a comparison spot plot of three triplet designs and the Plossl (ref. 1). This figure is purposefully like ref. 1's figure 5 (see TELESCOPE MAKING #19) to facilitate comparison with other eyepieces. Spot plots are shown on axis, and at 10, 20, and 25 degrees off axis. Indications are given of the amount of lateral chromatic aberration with each spot diagram in the

figure 4.
Comparison spot plots for Plossl and three triplet eyepieces.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TRIPLET C
COLOR
>12
3*
6
• 1′
5′
+ RED
o YELLOW
× BLUE
* INCLUDES PARABOLOIDAL COMA

Prescriptions of Triplet Eyepieces

	Triplet A	Triplet B	Triplet C	
R_1	4.0	plane	11.43	
T_1	.30	.18	.20	First Lens Negative
	1.517/64.2	1.517/64.2	1.517/64.2	
$D_{1/2}$	.70	.25	.61	
R_2	.6667	.50	.5442	
T_2	1.10	1.25	1.18	
	Air	Air	Air	
R_3	2.0	4.0	2.0	
T_3	.50	.90	.50	Second Lens Positive
	1.648/33.9	1.805/25.4	1.648/33.9	
$D_{3/4}$	1.55	.95	1.48	
R_4	-2.0	-4.0	-2.0	
T_4	2.00	2.30	1.90	
	Air	Air	Air	
R_5	2.0	2.0	6.669	
T_5	.50	.36	.30	Third Lens Positive
	1.517/64.2	1.620/60.3	1.517/64.2	
$D_{5/6}$	.87	1.37	1.40	
R_6	-2.00	-2.00	-1.177	
Focal Length, f	1.247	.638	.944	
E	.69	1.61	1.09	
e	.55	2.52	1.15	
Field Stop Distance	1.85	1.56	1.79	
Focal Plane Distance	1.04	.859	.805	

form of the locations of the red, green and blue principal rays. The center of the field is to the left, and the spot diagrams have been reversed so that they correspond to the visual image of a star through the eyepiece. One minute and five minute of arc circles are shown for the evaluation of on axis and off axis performance; spot diagrams are not shown when the spread substantially exceeds 12 minutes of arc. Note that all eyepieces are substantially perfect on axis. This reflects the relative ease of obtaining sufficiently good spherical aberration correction in an eyepiece. Note that these spot plots are for the position of best focus and *not* for the axial position as in the TELESCOPE MAKING #19 review article.

The three triplet designs presented are denoted A, B and C. Prescriptions for the three triplets are given in the table. The usual convention of positive radii being convex to the incident light is followed. The radii, thickness and spacings are those shown in figure 2. The D values are diameters necessary to avoid vignetting at the field diameters and apertures discussed below. Also included inthe table are focal length f, eye relief E, ratio of eye relief to focal length e, distance from first vertex to the objective focal plane, and the distance of the field stop to the first vertex of the last lens. The radii have been left with round-number values, producing somewhat odd focal lengths, so that certain relations between the radii useful for construction are made clear.

The A design uses common crown and flint glasses and has equiconvex positive lenses with identical curves. The spread in the spot diagrams compares very well with the Plossl eyepiece at f/15 and is only a little inferior at f/6. The A triplet is not usable beyond 20 degrees even at f/15 because of extreme flare in the image. The Plossl can be used at 25 degrees at f/15 but not at f/6. It is remarkable that such a simple eyepiece can produce imaging comparable to the more complex Plossl design.

Triplet B uses less common — though not exotic — glasses to produce a large eye relief while maintaining imaging comparable to triplet A. Imaging beyond 20 degrees is not useful, but within this field the 5 minute criteria is met even at f/6. The imaging for this design is perhaps a little better than the reference Plossl within the 20 degree field. The simple double convex lens forms have been retained, although the radii of the two lenses now differ.

Triplet C is an example of the results of departing from the simple lens forms used in A and B. This design has been subject to a little "hand" optimization, and illustrates the possible performance of a fully optimized triplet eyepiece. The spot diagram at f/15 is virtually perfect, so diagrams for f/6 and f/3 are shown. At f/6 the five-minute criteria is easily met at a 20 degree field angle,and is exceeded only slightly at 25 degrees. The imagery is thus comparable to more complex forms like the Fleischman. The spot diagram at f/3 includes the coma introduced by an f/3 paraboloidal primary since this eyepiece introduces compensatory coma of the opposite sign. The imaging at f/3, while not perfect, exceeds the five minute criteria only slightly over a 20 degree field. Triplet C would thus be an ideal eyepiece for a fast Dobsonian. Additional designs can be found in reference 2.

Construction Hints

Constructing one of these triplet

eyepieces may seem a formidable task, but should be fairly easy for anyone with a little experience in lens making. The tolerances required are not stringent; it is only necessary to be within 5% of the design values for all radii, spacings and thicknesses with the exception of T4, which should be held to within 2% because the lateral color depends strongly on this spacing. These large tolerances are possible because eyepieces are compromise designs as noted above. No single aberration is completely corrected — so that a construction error which may increase an aberration in one part of the field will be likely to decrease it in another. Also, should a completed eyepiece exhibit excessive lateral color, this can be corrected by adjusting T4. Close attention should be paid to mounting the lenses so that their optical axes are parallel and coincident.

Because of the numerical relationships between the radii needed for triplets A and B, it is possible to use standard ball bearings as reference spheres for truing the tools used in grinding. The bearing itself could be a tool for a concave surface. Ball bearings are available from a number of sources (ref. 4). For example triplet A can be made using a 1½-inch sphere (R1 = 0.75 inch), and ¼-inch sphere (R2 = 0.125 inch), and a ¾-inch sphere (R3 through R6 = 0.375 inch). This gives a focal length of 5.94mm (0.234 inch). The unit length is $^3/_{16}$ inches, so that all thicknesses and spacings are multiplied by 0.1875 inch.

In a similar way triplet B can be made using a ⅛-inch (R2 = 0.0625 inch), and 1-inch (R3 = R4 = 0.5 inch) and a ½-inch (R5 = R6 = 0.25 inch) to give a focal length of 2mm (0.080 inch). The first surface, R1, can be any convenient value much longer (more than 100 times longer) than the eyepiece focal length. The unit length is ⅛ inch so that all spacing and thicknesses are multiplied by 0.125. Triplet C does not share these even ratios of radii so that conventional means must be used to determine the radii.

TELESCOPE MAKING #3 contains detailed instructions for making lenses using only a spindle and glass tools (ref. 5). Russell Porter (ref. 6 and 7) has given instructions for making lenses using simple equipment and metal tools. More advanced techniques are to be found in *ATM Book 2* (ref. 8) and elsewhere, although these advanced techniques often presume a lathe and special tooling.

The crown and flint glass obtainable from A. Jaegers (ref. 9) (1.517/64.5, and 1.649/33.8) are near enough to the Schott glasses for use in triplet A and triplet C. The higher index crown 1.620/60.3 needed for triplet B is also available from A. Jaegers. The quality of glass needed for these eyepieces is not high, striae are relatively unimportant because of the small diameter of the light beam. Bubbles and seeds that could be ignored in glass for an objective should be avoided as they can obstruct a significant portion of the small beam.

Conclusion

The triplet eyepieces presented here represent a significant advancement in the technology of telescope eyepieces. They feature long eye relief, work well with fast primaries, and have the possibility of compensating for the coma of a paraboloid. These eyepieces use common glasses and are sufficiently simple for the amateur to experiment with.

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9. A. Jaegers Mail Order Catalog, 691 Merrick Rd., Lynnbrook, NY 11563.

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(Required by 39 U.S.C. 3685). 1A. Title of publication: Telescope Making. 1B. Publication No.: 01905570. 2. Date of Filing: September 30, 1983. 3. Frequency of issue: quarterly. 3A. Number of issues published annually: 4. 3B. Annual subscription price: $12.00. 4. Complete mailing address of known office of publication: 625 E. St. Paul Ave., Milwaukee, WI 53202. 5. Complete mailing address of the headquarters or general business offices of publisher: 625 E. St. Paul Ave., Milwaukee, WI 53202. 6. Full names and mailing addresses of publisher, editor, and managing editor: Publisher, Robert A. Maas, 625 E. St. Paul Ave., Milwaukee, WI 53202; Editor, Richard Berry, 625 E. St. Paul Ave., Milwaukee, WI 53202; Managing Editor, Katherine Bond, 625 E. St. Paul Ave., Milwaukee, WI 53202. 7. Owner: AstroMedia Corporation, 625 E. St. Paul Ave., Milwaukee, WI 53202, whose owners are David L. Walther, 625 E. St. Paul Ave., Milwaukee, WI 53202; Christopher Walther, Elizabeth Walther, Jennifer Walther, Jonathan Walther, Mark Walther, 625 E. St. Paul Ave., Milwaukee, WI 53202. 8. Known bondholders, mortgagees, and other security holders owning or holding 1% or more of total amount of bonds, mortgages, or other securities: none. 9. For completion by nonprofit organization authorized to mail at special rates (Section 423.12 DMM only): not applicable. 10. Extent and nature of circulation: 10A. Total number of copies printed (net press run): average number of copies each issue during preceding 12 months: 3,531; actual number of copies of single issue published nearest to filing date: 3,500; 10B. Paid circulation: 10B1. Sales through dealers and carriers, street vendors, and counter sales: average number of copies each issue published nearest to filing date: 333; actual number of copies of single issue published nearest to filing date: 329. 10B2. Mail subscription: average number of copies each issue during preceding 12 months: 2,006; actual number of copies of single issue published nearest to filing date: 2,155. 10C. Total paid circulation (sum of B1 and B2): average number of copies each issue during preceding 12 months: 2,339; actual number of copies of single issue published nearest to filing date: 2,484. 10D. Free distribution by mail, carrier, or other means of samples, complimentary, and other free copies: average number of copies each issue during preceding 12 months: 49; actual number of copies of single issue published nearest to filing date: 50; 10E. Total distribution (sum of C and D): average number of copies each issue during preceding 12 months: 2,388; actual number of copies of single issue published nearest to filing date: 2,534. 10F. Copies not distributed: 10F1. Office use, left over, unaccounted, spoiled after printing: average number of copies each issue during preceding 12 months: 1,143; actual number of copies of single issue published nearest to filing date, 966. 10F2. Return from news agents: average number of copies each issue during preceding 12 months: 0; actual number of copies of single issue published nearest to filing date: 0. 10G. Total (sum of E, F1 and 2 — should equal net press run shown in A): average number of copies each issue during preceding 12 months: 3,531; actual number of copies of single issue published nearest to filing date: 3,500. 11. I certify that the statements made by me are correct and complete. Robert A. Maas, Publisher.

Wooden Tubes for Telescopes

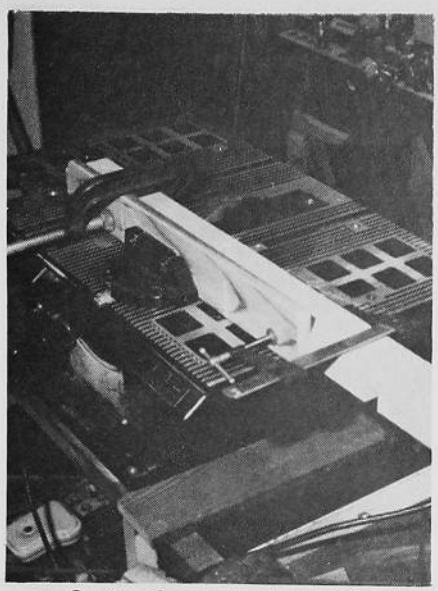
Making outside ring cuts (note router bolted upside down to table).

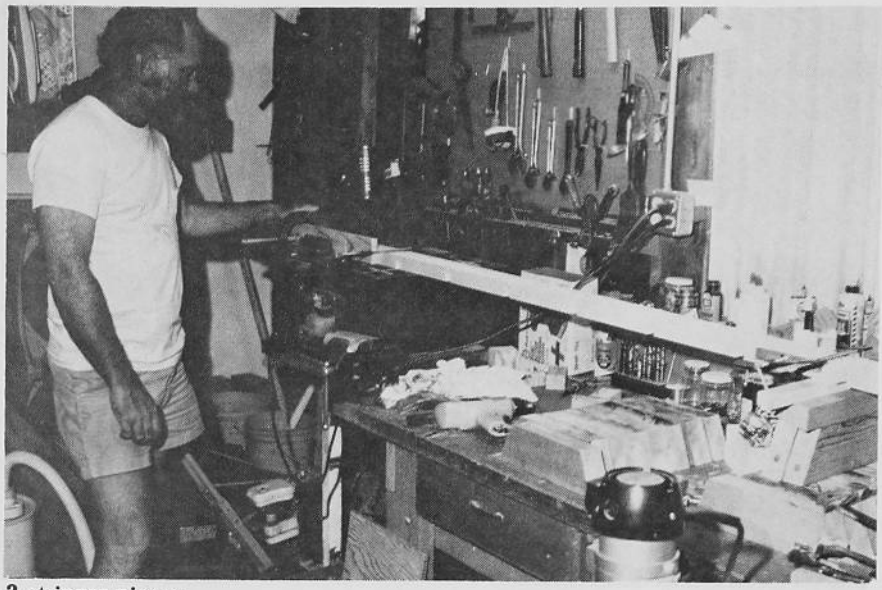
To minimize reflections the inside ring surface was spackled and sanded several times.

After looking over and through all the fine telescopes at the 1981 Riverside Telescope Makers Conference, it occurred to us that we had not seen any *round* wooden tubes. Every other shape was represented: square, octagonal, open frame, cardboard Sonotube, etc. On the drive home from the conference we mulled things over and decided to build an esthetically pleasing telescope with a round wooden tube, rotatable, of course, so the eyepiece could be positioned for maximum viewing comfort. We chose Coulter Optical's 17 ½″ mirror set to be the heart of our instrument.

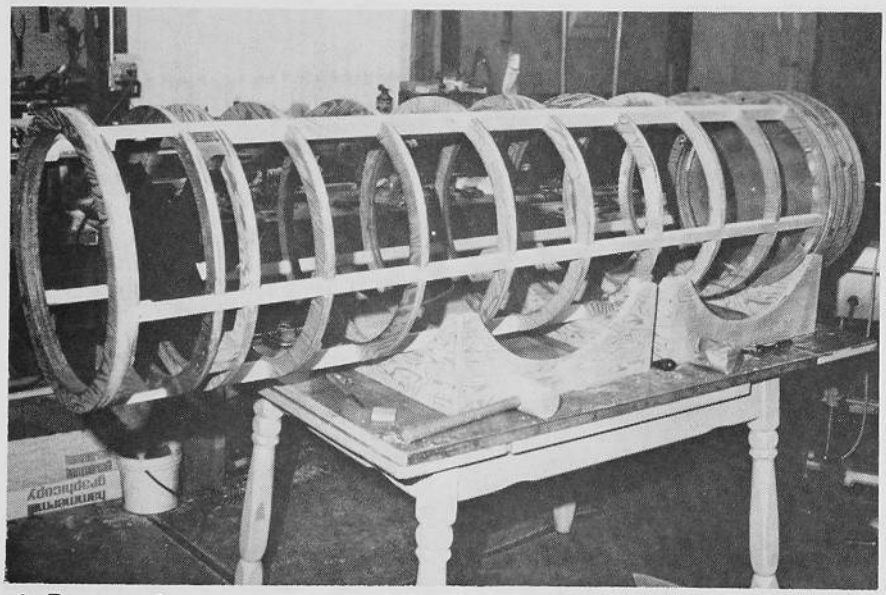
In order to test our design ideas we decided to build a mock-up two feet long with three plywood ribs (rings) spaced on 12″ centers. We used a mahogany doorskin to test the wrapping procedure which is shown in the pictures and described later. We decided that in our finished tube we would need to use ¾″ plywood cut 1½″ wide for the rings and that a spacing of about 9″ center-to-center would make the tube strong enough.

We finally arrived at the point where the only thing left to do was to start building. We had cut the rings (ribs) for the mock-up with a sabre saw and although they were useable, the edges were not very square. We thought a band saw would probably work, but didn't have access to one. Our solution was to use a router attached to a jig that would accurately center each piece of plywood. It was necessary to make two cuts on each piece of plywood, an outside and an inside cut. We made all

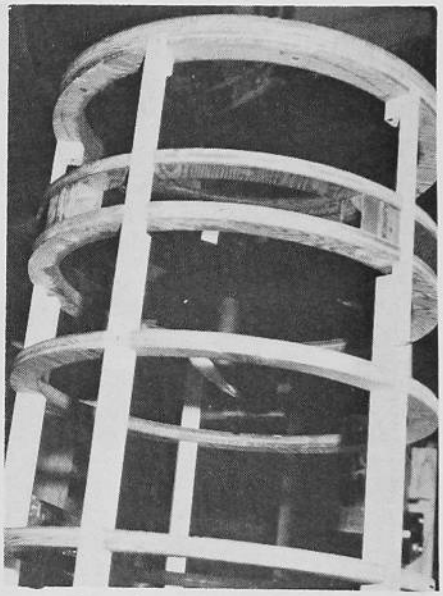




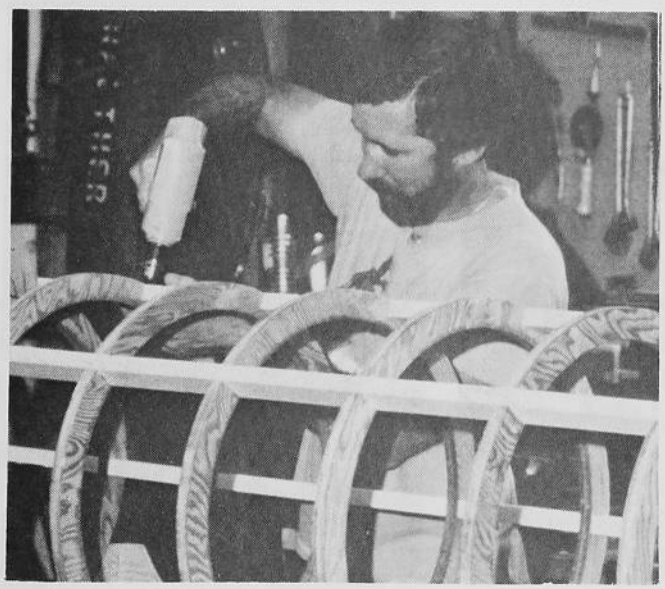
▲Cutting the positioning notches in the 3 stringer pieces.

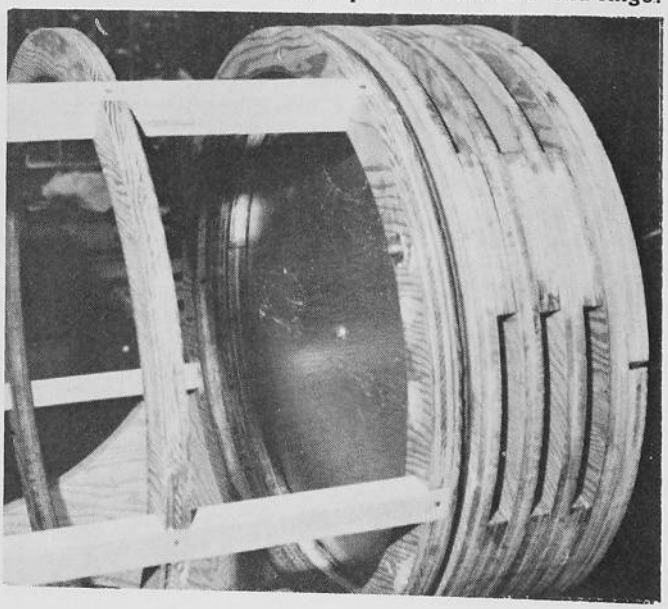


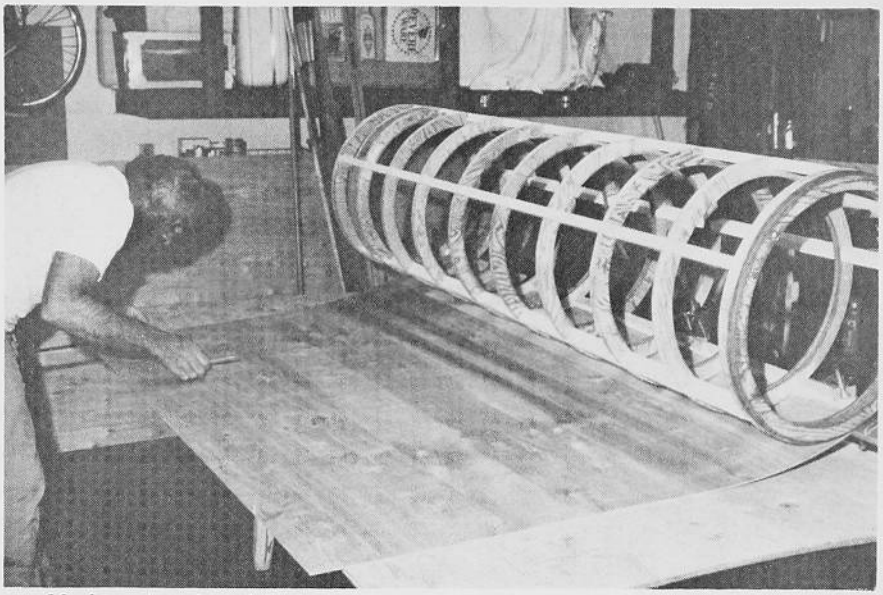
▲ Framework was glued and screwed at every joint.



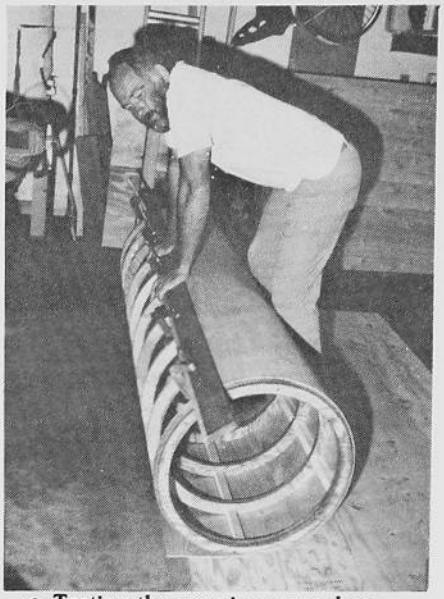
▼Completed framework end rings.



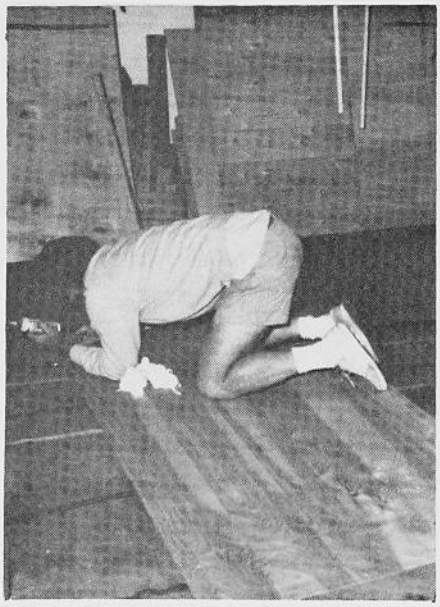




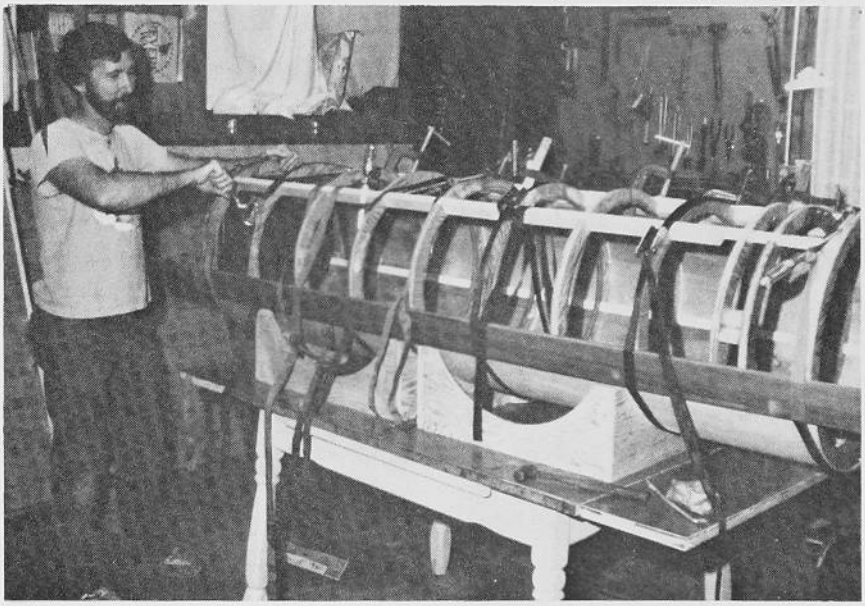
▲Marking the edge of the first skin section.



▲Testing the wraping procedure.

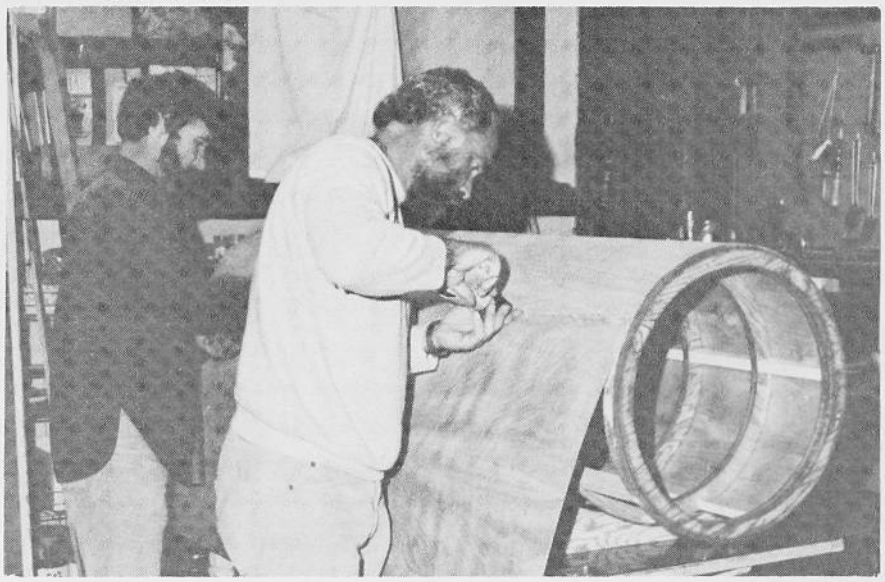


▲ ready to apply glue.



▲ First skin section glued and clamped.

▼Drilling holes for the spider



the outside cuts first and then the inside. This system worked great, and we ended up with 16 accurately cut ribs.

Since the focal length of the mirror might vary from nominal by as much as 3%, it was necessary to design a spider attachment that could be adjusted to its final position after we received the mirror. In the end, we came up with an assembly consisting of two rings and four blocks notched and drilled to accept the vanes of the spider. The blocks are then screwed to the rings with the spider inside. This arrangement eliminates any possible concern about overtightening the spider vane tension since the force is borne by the tube rings, not the tube wall.

Knowing that a tube diameter of 21¼″ would take more than one 4 x 8 sheet of ⅛″ plywood to wrap, we decided to use five basswood stringers located equally around the circumference of the tube. The stringers serve two purposes — they accurately line up the ribs and they give a place to attach the edges of the sheathing. We cut them out of a single piece of basswood on the table saw. Three are ¾″ x 1″ in cross section and two are 1″ wide to facilitate attaching the sheathing edges. The stringers were clamped together and notched for the ribs on the table saw using dado blades.

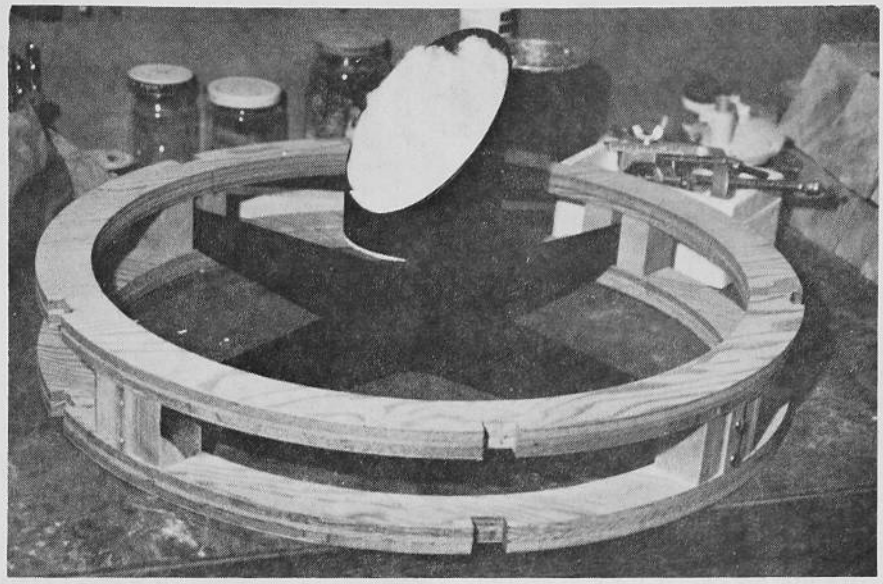
Next, the rings had to be notched for the stringers. We built a jig that would hold each ring perpendicular to the dado blade and allow us to rotate the ring to the next cutting position. The notching worked out so well that the front and rear rings of the finished tube are exactly parallel.

Before we could assemble the framework, it was necessary to do a few things first. Both end rings are doubled up and these had to be fitted and glued. We also drilled holes for three locating dowels in the mirror end ring and for three mirror cell mounting bolts. Once these tasks were completed, it didn't take long to assemble the framework using woodscrews and glue at all joints.

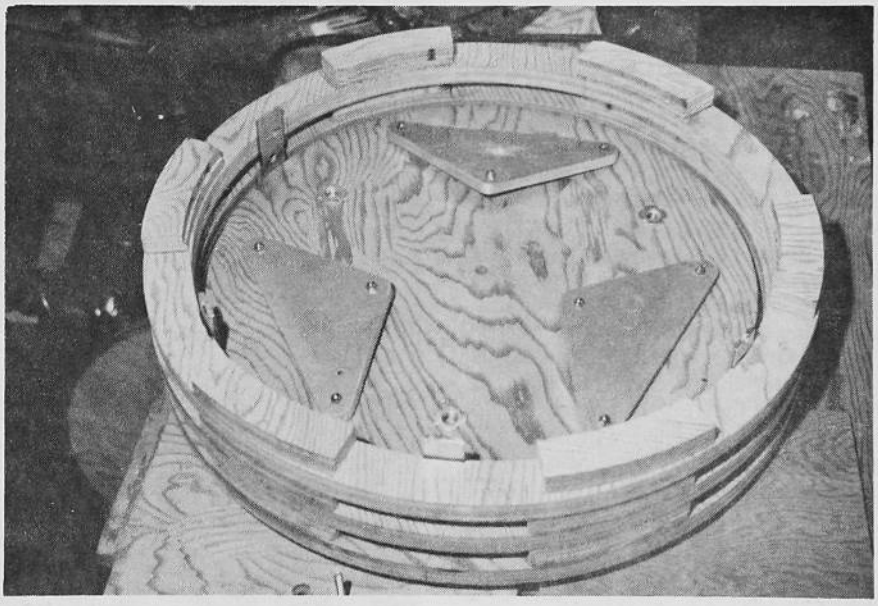
Now we were ready to apply the skin. We carefully measured and cut the first piece of plywood 40″ wide by 74½″ long, enough to cover ⅜ of the circumference. We lined up the plywood along one of the 1″-wide stringers and clamped the edge of the plywood in place. This allowed us to bend the plywood around the frame to check the plywood's alignment. Then we drilled holes approximately 1″ apart all along the edge of the plywood and installed the screws. With this edge firmly attached, we again bent the plywood around the frame and predrilled the holes along the opposite edge.

Our method of bending the plywood in these operations was to just roll the whole assembly on the garage floor. In order to hold the skin in place, we used three 1″ strap clamps and numerous tourniquet clamps made of nylon webbing.

The skin was now ready to be attached permanantly. We removed the skin from the framework and applied glue to the starting stringer and inside of the plywood. Then we reattached the plywood and installed all the screws. Working rapidly, we placed the assembly on the floor and glued all ribs and stringers plus the contacting area on the inside of the skin. Next we rolled the skin on, tightened the clamps and installed all the screws along the second edge of the skin. We left the clamps in place while the glue dried. The second skin, which is narrower, was installed in exactly the same manner as the first.



▲Spider assembly



▼Partially completed mirror cell.

The mirror cell was constructed in the same manner as the tube with the exception of being considerably sturdier. The skin was cut from the same piece of plywood used for the tube so that the grain of the wood would match.

The front edge of the tube and rear edge of the mirror cell were finished with crown moulding. The two side seams were covered with strips of birch wood tape glued in place. The inside was painted with flat black Rustoleum and the outside is finished with natural Jasco Oil.

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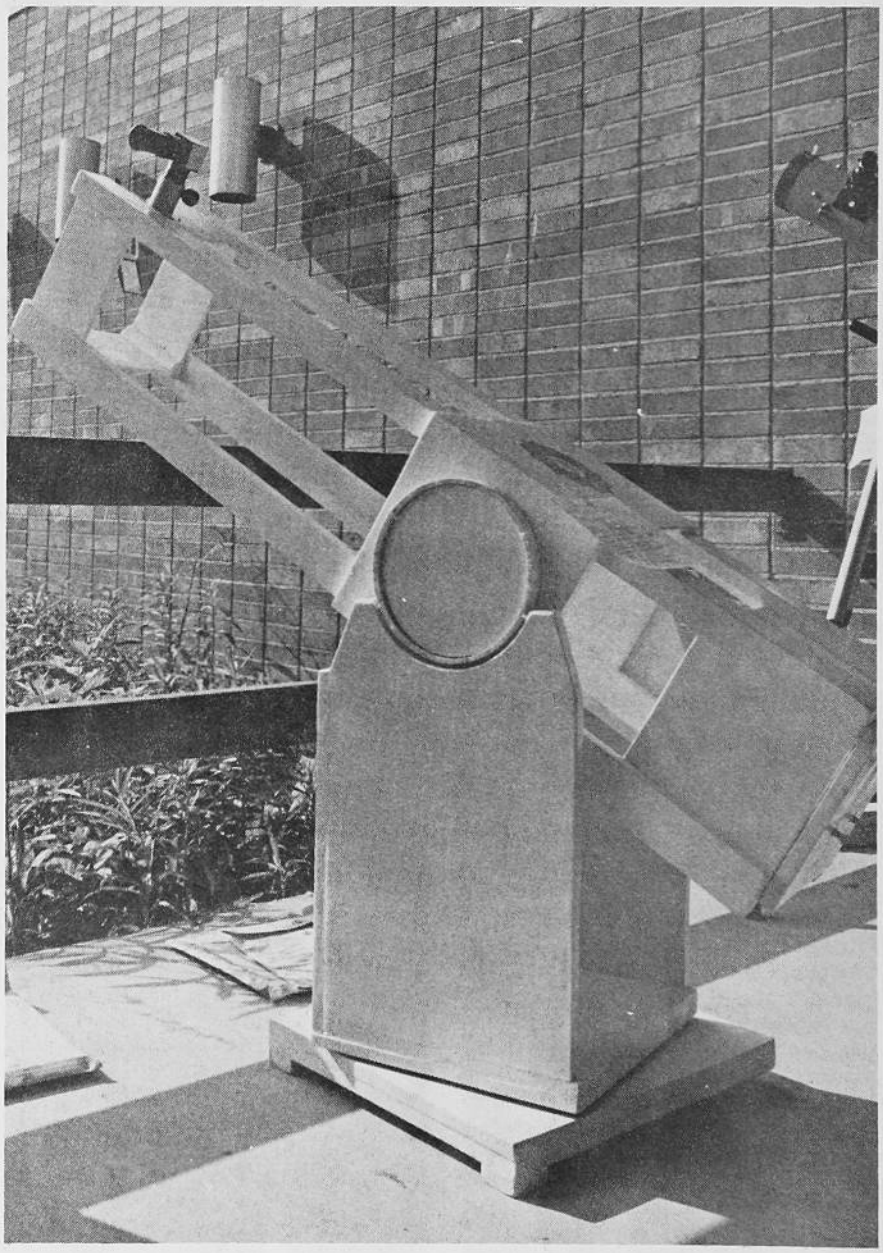
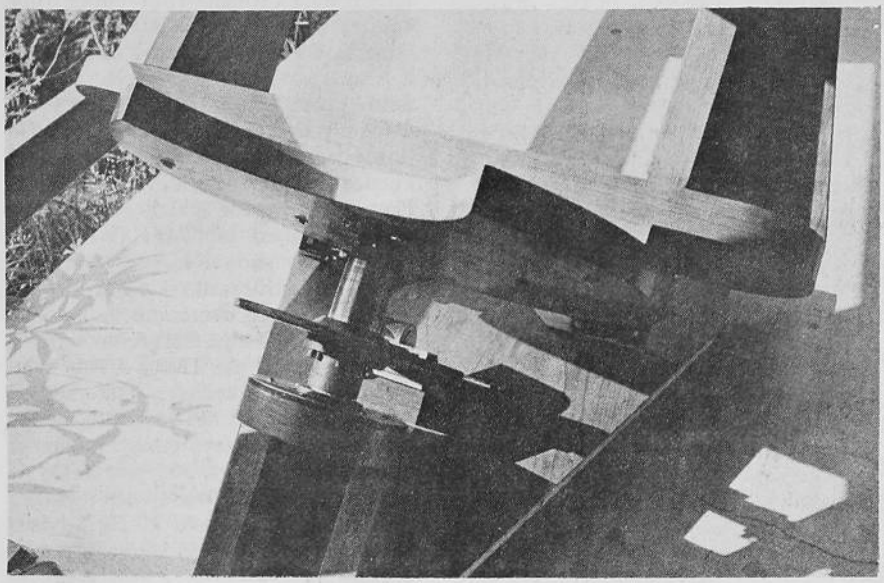
The 1983 Apollo Rendezvous and Telescope Fair

The first hot days of the year arrived simultaneously with the Apollo Rendezvous last June 10 and 11. This was not unexpected. In fact, if any Apollo Rendezvous happened to coincide with a period of cool weather, Ohio people would mumble and scan the skies for the other signs of impending doom. Different from past meetings was the clear weather that graced this one. Two clear nights in an Ohio June is miracle enough — but the fact that they came during the dark of the Moon and during an astronomy gathering is spooky.

Attendance at this year's Rendezvous was greater than I had anticipated (I thought that the Texas Star Party would steal more people away), with about 120 people visiting the Dayton Museum of Natural History where the Apollo



This solar telescope, shown by Tom Burns of Columbus, Ohio, is of the design popularized by Robert Pike. Rather than using filtration to lower the Sun's brightness, it uses extreme inefficiency of its reflective surfaces and the polarization of light reflected from dielectrics (such as glass). The advantage of this system is that an ornery kid can't remove your otherwise safe filtration — the telescope is already operating at full capacity. Another nice feature is the colorless white solar image. It uses an unaluminized Pyrex primary (6-inch f/10), and unaluminized Herschel wedge secondary, and a Herschel wedge tertiary placed in an orientation at 90° to the secondary. (The reason it's so polarized is because the angle of reflection, 45°, is close to Brewster's angle, 56.6°, where the reflection would be totally polarized.) Note that Mr. Burns performed the unusual move of painting the inside of the telescope white. This is to put off as long as possible the deleterious effects of solar heating of the telescope. The inside of the focuser tube and the area behind the tertiary (that thing that looks like a star diagonal) are carefully blackened. The result is a beautiful image of sunspots, pores, faculae, and granulation.



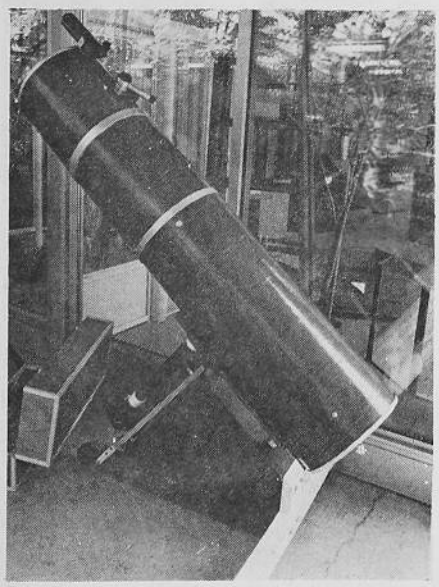
Dick Harmer's award-winning wooden 10-inch f/5.6 was finished with veneer. Its mount featured a wooden disk acting against two rollers to move in R.A. (at least it was most of a disk; he had a round section cut out of it to allow pointing at southerly declinations). One feature of this telescope that doesn't show in the photo is the easily rotated tube assembly. A mal-placed eyepiece in certain areas of the sky is always a problem with large equatorially-mounted Newtonians. One other solution to this problem that I saw was in John Graham's similarly mounted 10-inch reflector (not pictured). He has three simple focusing tubes on various sides of his tube and a diagonal that moves in click-stops around to point at the most convenient of them. I could never own Harmer's telescope because I am too much of a slob. He was always rubbing down the veneer and waxing the telescope; my telescopes are lucky if I don't get too much dirt on them.

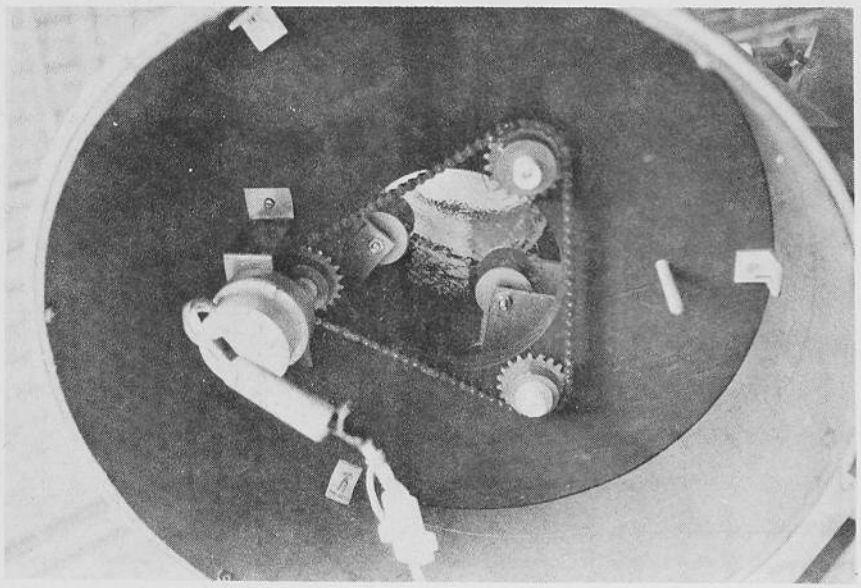
Observatory is located and where the Rendezvous is held. Particularly gratifying was the heavy participation in the Telescope Fair by those attending.

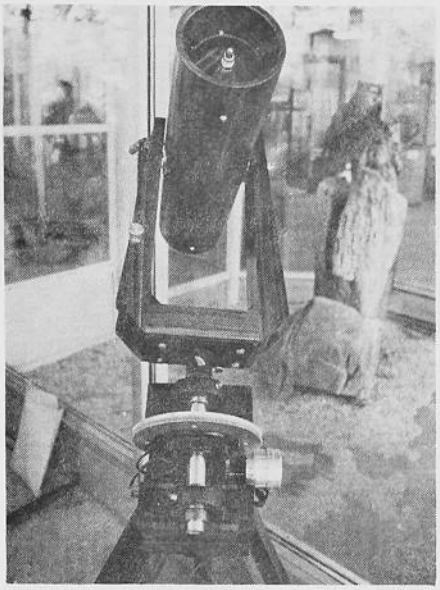
The Friday night slide session is my special favorite, and this year it was particularly good. For those who don't know about this custom, let me explain that the Friday night meeting is a first-come, first-served session where amateurs can show slides and give off-the-cuff talks. These talks are less formal than the organized papers given the next day and are often more entertaining. This year we were treated to the adventures of an itinerant observatory and lots of colorful slides of a spectroscopic test of nebula filters. Even a few pictures of Comet IRAS-Araki-Alcock were shown, but I had the distinct feeling that more photos of the comet were taken. (Perhaps no one brought their photos because they thought everyone else would bring theirs.) Most importantly, this year no one showed boring vacation slides.

After the slide show ended, we all repaired to the Junior Observatory roll-off roof, where the telescopes are old but the optics are good, and viewed a somewhat turbulent image of Venus. One local telescope that was interesting was an off-axis Schmidt-Newtonian that gave an unobstructed view. It gave a

Ed Jones displayed his bright red 12.5-inch f/5. This award-winning instrument features a built-in off-axis guiding eyepiece and focuses by an electric motor on the primary mirror. This mirror focusing method is comparatively rare on Newtonian telescopes although it is common enough on commercial Schmidt-Cassegrains (probably due to the amplification of the focusing motion by the secondary). I know that using an electric motor for focusing sounds like needless luxury, but it really can make a difference in high-power planetary photography, where the slightest touch can send the planet dancing out of the field. The closeup shows the rear side of the mirror cell.







A dual award-winner and a really beautiful telescope was brought by Steve Rismiller. It features 4-inch Schmidt-Newtonian optics (made by a now-dead company called Optron) and effective woodworking by Mr. Rismiller. Steve fashioned this tube and fork from walnut. It has a spring-loaded declination adjustment that was made similar to old surveying instruments (he gave a talk about this). Yes, that is an out-of-focus owl in the back. The covered walkway where telescopes are set up is near (and on good years, upwind of) a miniature zoo kept by the Dayton Museum of Natural History. This zoo offers convention-goers nearly as much fun as the convention.

refractor-like image, but without the violet halo of the residual color aberration characteristic of achromats. It was very impressive.

When we got tired of slapping mosquitoes (the Dayton Museum is surrounded by a rain forest or jungle or something), we went up to the main dome that houses the 0.5-meter Cassegrain instrument. This was a special occasion for me. I've attended four Rendezvous now, and I have never see this telescope in action. It gave a superb view of Saturn between bouts of bad seeing, which proves that even the much maligned Dall-Kirkham optical system can perform well if the mirrors are lined up.

On Saturday, the Apollo Rendezvous got down to its main business, which is the Telescope Fair and the paper sessions. There were more TM talks than in recent memory, probably because Richard Wessling, a well-known Midwestern telescope maker, chaired in the afternoon and he had strong-armed the Cincinnati contingent into giving talks — as well as giving one himself.

The Columbus Astronomical Society was showing its 16-inch (I mentioned it in my article in TM#19), so first I had to participate in setting it up, but once we were finished, I looked back at the covered walkway and saw a lot of other telescopes. The Texas Star Party didn't get 'em all!

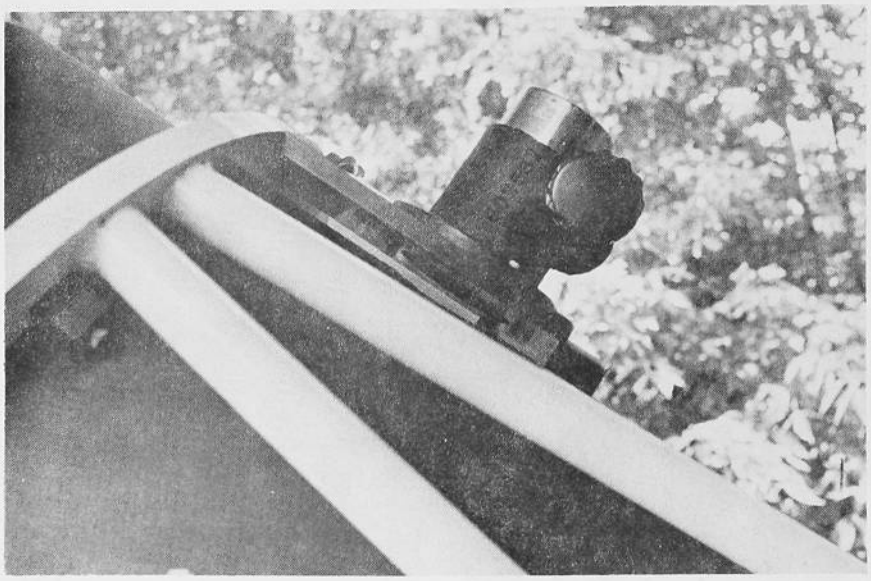
I intend to cover in the photo captions the telescopes shown, so I won't belabor them here, but if there is any message to be read in this year's Rendezvous, it's **The Pipe Mount Is Not Yet Dead** — at least not in Ohio.

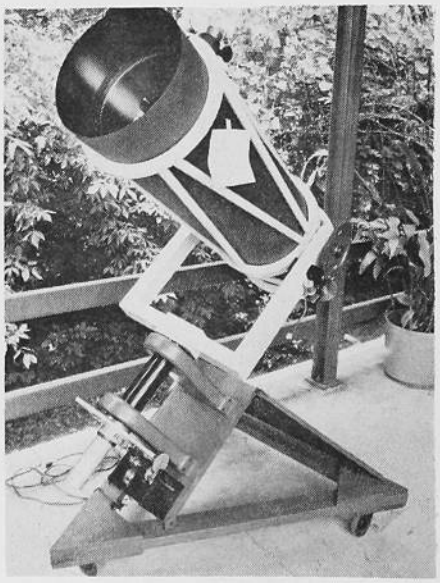
This was elaborated by John Graham in his excellent talk "Designing Inexpensive Equipment for Amateur Astronomy." He uses a pipe equatorial head but puts it on a wooden base. This way, all the vibrations of pure pipe mounts are damped out by the wood. He makes all of his telescope parts, including the diagonal which he selects from pieces of flat glass, by testing them against a reference flat. He makes a mirror cell which uses plastic foam instead of the more usual compression springs. I think that the only commercial service he uses is aluminizing, and I'm not too sure about that.

Another great talk was "The Schiefspiegler's Optics Aren't So Tough" by Richard Wessling. He described the various trials he encountered in building an 8-inch Kutter Catadioptric Schiefspiegler of the type described in TM#4 [Wessling's telescope is shown in the article on AstroFest in this issue — ed], and what he had done to overcome them. One point he made is his disagreement with the authors of the TM#4 article who chose to make an ordinary lens and then decenter it to get the requisite wedge effect. Wessling says wedge is almost unavoidable anyway, so you might as well accept it and work with it rather than work to remove it. He advises shooting for the correct wedge from the beginning.

The Apollo Rendezvous has had continual trouble deciding what kind of awards to give, and this year was no exception. Problems in the past included giving "joke" awards and too many awards. This year the awards were more in a "contest" mood than a "merit" mood (see the editorial in TM#6). I preferred the "merit" award system because it allows each judge to decide just exactly what it was about a particular telescope that he liked (if he

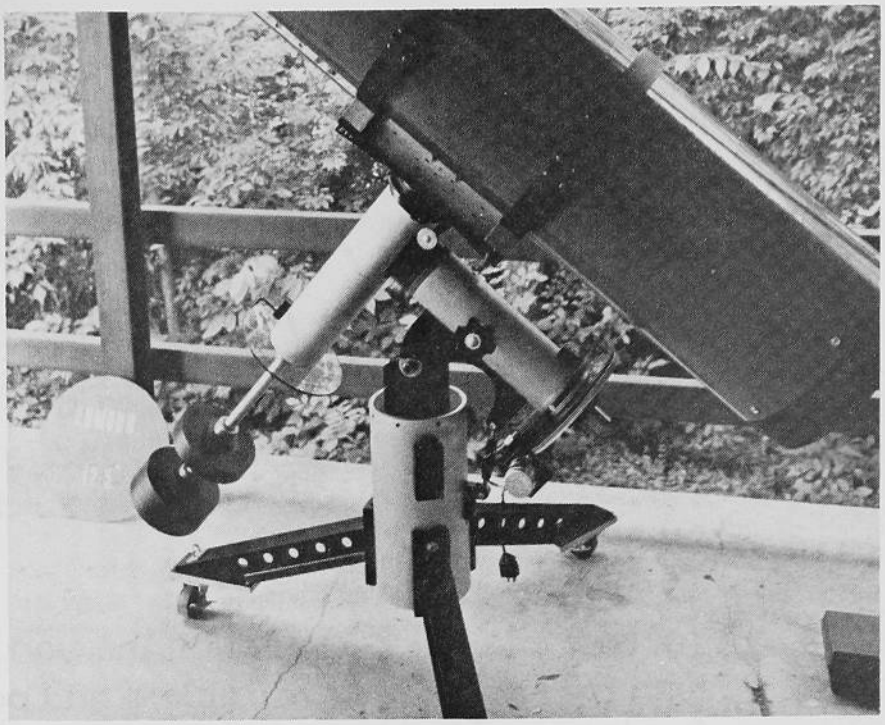
More Schmidt-Newtonian optics by Optron are shown here in a 12-inch f/4.5 Serrurier tube assembly by John Lawson. The inner black tube is made out of thin sheet material and serves only as a dewcap/light baffle/heat current shield. It adds no structural support — that is already handled admirably by the strut tube design. Since the black tube is so insubstantial, a focuser can't be attached to it. Mr. Lawson cured that problem with the sideways solution shown in the other photo.





liked anything) and give the award for that particular thing. Happily, this year's award winners would have won either a "merit" competition or a "contest" competition, but it might not always be so. One other procedure I would change is the announcement of the awards after the scopes have been taken down. The award-winners should be labeled sometime during the day so that people can identify the telescope that won an award and take a closer look at it.

The final activity was a star-gaze at John Bryan State Park Observatory, a former Air Force facility for satellite tracking. When the technology for satellite tracking changed, the Air Force closed its observatory there and offered it to the Miami Valley group. The result was that they got a beautiful observatory for free that they couldn't possibly have afforded if they had to pay for it themselves (ain't DOD grand?). The observatory contains a motorized roll-off roof area as well as a conventional metal dome. Full support facilities on the ground floor include a warm-up room and a darkroom. It has excellent security, being surrounded by a ten-foot chain-link fence topped by barbed wire and protected by an electronic system that would stop an international jewel thief (leftovers from the Air Force's tenancy; all a jewel thief would find to steal today would be some stale Vanilla Wafers). Presently, they have 12.5-inch and 16-inch reflectors set up in the observing areas.



This 12.5-inch f/6 Edmund tube assembly was exhibited by Bob Tauber primarily for the modifications to the (non-Edmund) mounting (like those beautiful Lucite setting circles, for example), but was almost uniformly admired for its optics. Further conversation with Bob revealed that Edmund made about 30 of these tube assemblies but only sold about 3 before they gave it up as a bad attempt and dismantled the unsold telescopes for parts. The blood cousins of this 12.5-inch mirror are probably still on the shelf at the Edmund Scientific Co., and anyone who is willing to swallow hard and pay what they ask would get an equally incredible telescope mirror. I personally would like to talk to the optician that made the mirror to offer my congratulations.

Everybody set up on the grass outside, but oddly there wasn't a total one-to-one correspondence between the telescopes we'd seen in the telescope fair and what we saw set up here. Mr. Wessling had his 8-inch Schiefspiegler there, but it had spent too much time in the rear of his hot car and it never cooled down in the brief time that was allotted for observing. The star of the evening was Bob Tauber's 12.5-inch f/6 Edmund Scientific reflector. The optics were fantastic! We had fairly good seeing that night and Saturn was as high as it was going to get. I went around looking through various instruments. If Cassini's division was visible at all through most of them, it was showing itself as a black line, but through Tauber's telescope, it looked like a broad avenue! Clearly, Edmund took care with surface smoothness as well as overall correction. Here's a warning to refractor owners: Don't set up near this instrument unless you're fond of embarrassment.

Unfortunately, we got only about one hour of full-darkness observing time before we were thrown out. C'mon guys! You said in your brochure that we would be observing "until the cows come home." Where I come from, that statement means dawn, when cows return to the barn to the milked. Perhaps a message could appear in next year's brochure telling people the exact time you intend to stop observing, or at least a warning that Dayton cows come home "slightly beyond the end of evening astronomical twilight." (Do you get the impression that I am slightly peeved at never getting to look through a cooled-off Schiefspiegler?)

Still, it was a good convention, and the first Apollo Rendezvous that I can remember that had an active effort to find TM talks. Previous Rendezvous have tried to be all things to all people, with the result that there was nothing for nobody. Perhaps this tendency to specialize in telescope making will result in higher quality talks. Maybe the Apollo Rendezvous can recapture some of the excitement of its early days and become an inland little brother of Stellafane and Riverside. I hope so.

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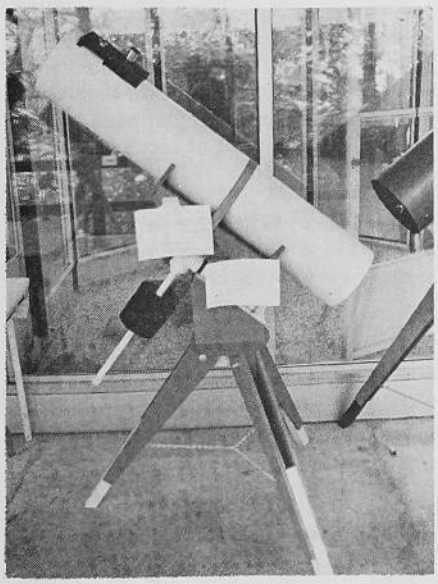
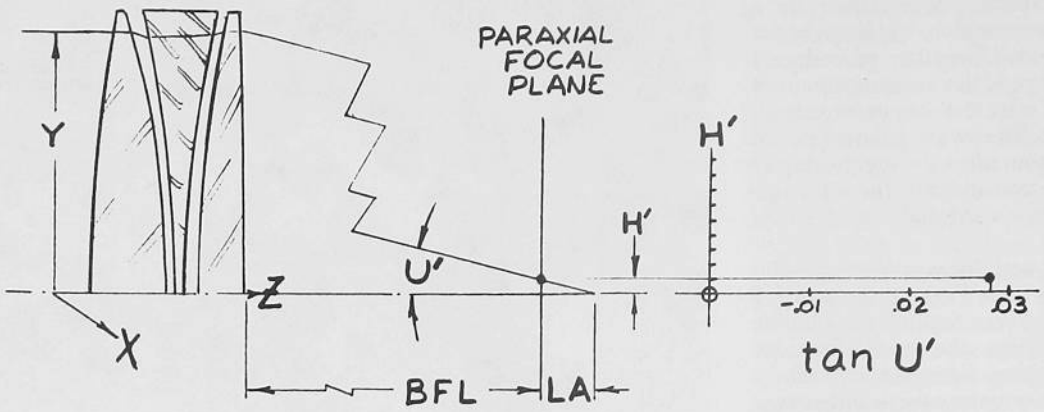
This 6-inch f/6.3 Newtonian was made by John Graham for $90 and contains no commercial parts. Note that the pipe equatorial head is held by U-bolts to a wooden platform. The counterweight was cast by pouring concrete down a cardboard tube. This telescope was later raffled-off by the Miami Valley Club. Although I have only one photograph of this type of instrument, there were enough clones of it displayed at the Fair to indicate that this design is popular around Dayton.





(a) Fig. 1 (b)

(a) Meridional (Y-Z) section through lens and focal area with axial ray of ht. Y refracting and passing the paraxial focal plane at ht. H' and angle U'. (b) Plot of H' vs tan U'.

The H'tanU' Curve:
A Most Favorable Ray Intercept Plot

Using modern computers, lens designers may choose any of several ways to analyze the image quality produced by a system under design. After a series of manual or automatic design iterations, the question always arises, "What is the nature of the remaining aberrations and where is the field of best imagery?". A most favorable way to find the answers is with the H'tanU' curve: a plot of H', the intercept height from the optical axis (usually in the paraxial focal plane), as ordinate versus tanU', the tangent of the ray slope angle with the axis.

This is shown in fig. 1a. The axial ray enters at some height, Y, above the optical axis, is refracted, and leaves the lens at the angle U' (which has negative or descending slope). It pierces the image plane at height H' before crossing the axis at a distance, LA, from the focal plane. This ray is plotted in fig. 1b at its H' and tanU'. The value of tanU' for the full aperture is $-1/2f\#$, or -0.033 for this f/15 example.

To reveal the size and nature of the axial image, simply trace a meridional fan of three or four rays through the upper half of the pupil (lens) in the colors of interest. Usually the d, F, and C lines are used (F is blue and C is red light); E and g light may be added for apochromats. Such a plot on axis in one color, fig. 2, shows the marginal ray corrected to the paraxial focal plane.

The geometric image size is determined by enclosing the curve between two parallel lines, remembering the untraced half of axial plots are mirror-imaged about both axes. We see all the light enclosed within paralled lines 0.001 inch apart which, at this focal length, is about two arc-seconds diameter. Figuring is in order here for apertures greater than two inches!

Note that the lines are rotated from horizontal to give minimum separation. This is really what happens during focusing. The shift of focus equals the slope of the lines, $-H'/tanU'$. In this case it is $-(.001/-.066)$, or 0.015", which is added to the paraxial BFL.

This plot also shows a residual zonal spherical of longer focusing rays, often seen in systems using steep curves to balance aberrations of flatter curves. Here the higher orders don't match completely, requiring aspherizing if too large to tolerate. Some Maksutovs and apochromats as well as most photographic lenses fall heir to this residual.

Plotting H' versus anything else doesn't give such a correct and direct measure of focal shift, especially for high field angles and high speed f#s.

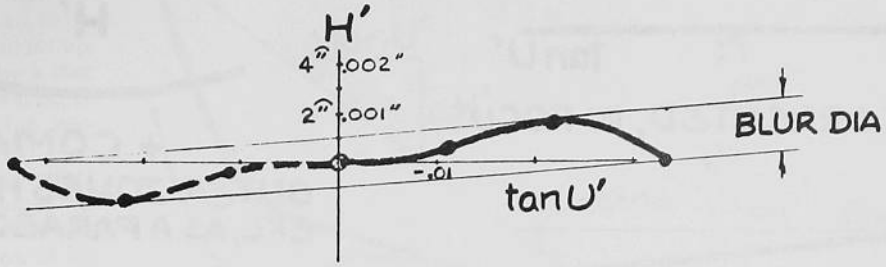


Fig. 2
H'tanU' plot of a meridional fan at paraxial focus, refocused $-\frac{\Delta H'}{\Delta \tan U'} = \frac{.001''}{.066} = +0.015''$ for a minimum blur of 0.001 inch (2 arc sec) dia.

Adding the plots of other colors of interest, we get an idea of the character of a white light image as seen in fig. 3. Here the d and E light stay close together, while the C and F cross over to give a half arc-second blur (with the lens figured to a null at the yellow-green wavelength). The faint violet halo of g light spreads to a 2-second radius, focusing somewhat behind all the rest of the colors.

What about the off-axis aberrations — coma, astigmatism, lateral color? Plotting in the same image plane, a full aperture meridional fan is traced from 1° below the axis in d and g light and plotted as in fig. 4. First, we see the plot is quite tilted, with the best focus toward the lens by −(.0047/−.066), or 0.07". A slight coma is also shown by the upward curvature component of the curve ends relative to the center of about 0.0007". Being 2.333" off-axis, this coma would appear as a 15 arc-second blur at the edge of a 60° field ocular — quite invisible to most observers. Lateral color is revealed by the vertical separation of the d and g chief rays, but again so slight as to be masked or compensated by the eyepiece design.

So far all tracing has been in the meridional plane, the plane of the paper. To check for astigmatism, we trace a fan of rays originating from the same infinity object point 1° off-axis but passing through the half aperture coming out of the paper at 90° — the x-axis in the coordinate system shown in fig. 1. Then plotting the Hx' (intercept height in the x-axis direction) versus the tanU', using the conventional dashed line as in fig. 4, we see a focal shift for the sagittal (skew) fan of 0.03": not as great as for the meridional fan and so the vertical difference, ΔH', represents the astigmatic enlargement.

Although the apochromatic lens traced in these examples is more complex than most amateur design projects, it illustrates the advantages of using H'tanU' plots. The various fans exhibit their telltale curves with far less raytracing than spot diagrams require.

Some common pure aberrations and residuals from a cemented achromat are shown in fig. 5. Compare these examples to the plot in fig. 4. Not only can you diagnose the separation of the C and f fans from the d fan, but you can also spot the change in spherical correction from undercorrected in the red to overcorrected in the blue. Airspacing, as Buchroeder and others have pointed out, greatly reduces this spherochromatism. Designers of apochromats always face this choice of improving tarnish resistance and light transmittance by cementing, or improving the color-correction by air spacing elements. In fact, it can be shown that for a given speed, KzFS4 airspaced apo's are better color corrected than the KzFS1 cemented apo's, even though the KzFS1 glass has the better match in blue and violet partial dispersions. An airspaced lens has been designed at f/15 which gives less than 1.6 arc-seconds geometric image spread in g light when focused for the d and E wavelengths.

Since H' is a direct measure of image spread in the focal plane, it is easy to take LA data published by others and convert it to H' plots to examine the resulting imagery. For instance, in TM#14, page 40, we may wonder what image spread results from the LA's graphed in fig. 4b. By multiplying each LA by its associated tanU', we obtain the H'tanU' plot. (Remember that tanU' for the full height of the f/23 pupil is −1/2x23, or −0.0217. Other values of tanU' are proportional to the full-height tanU' value.)

Fig. 6a shows this system with spherical optics, and fig. 6b shows the same system when figured to a null in d light. The spread of H' between the marginal and zonal rays amounts to

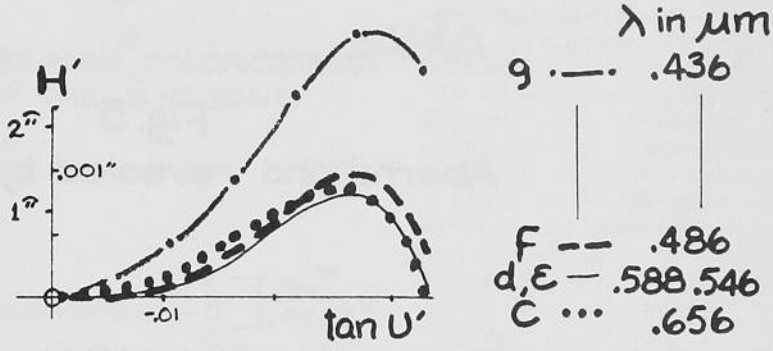


Fig. 3
H'tanU' plot of axial image in visual λ's

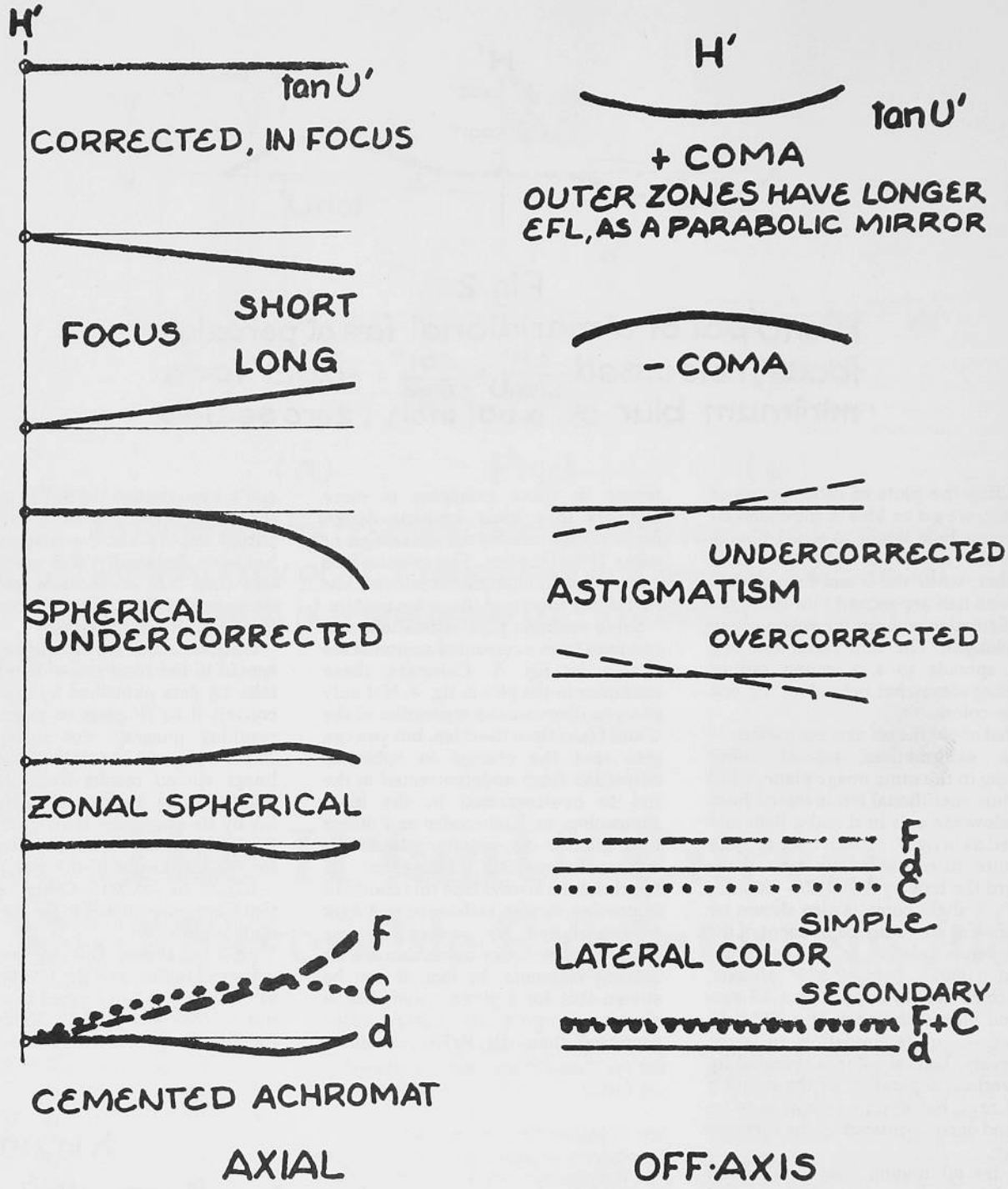


Fig. 5
Aberrations revealed by H'tanU' plots

0.0053 + 0.00069, or 0.00122 inch. Dividing by the focal length to get the angular aberration and multiplying by 206,265 arc-seconds per radian, we obtain a 1.8 arc-second diameter spread. This is helped somewhat by the effects of diffraction, but would still be a good candidate for aspherizing in sizes over six inches.

Fig. 6b shows a 0.76 arc-second diameter color blur remaining over the C and F spectrum. This is greater than

the minimum obtainable by the 0.8 height correction crossover design, to be sure, but is disappearingly small for up to six-inch telescopes shown by a star test with half the aperture covered. It compares favorably to the fine apo described in *S&T* (October 1981).

Conclusion: The H'tanU' plot, especially when H' is expressed in angular units of arc-seconds, shows at a glance the state of correction of an optical system in such a way that an easy and direct comparison may be made among several designs. One can see that a single curve graph of focus *versus* wavelength is insufficient to describe a lens with any degree of spherochromatism such as fig. 3 or fig. 5 shows, and fast cemented lenses usually have much more.

We have recently seen spot diagrams published which, although interesting when shown at large scale, do not give adequate information on where in the pupil the aberrations arise. A full set of spot diagrams through focus and through the half pupil, at various field angles and colors, can be a useful final presentation, but an expensive and time-consuming design tool relative to the H'tanU' plots.

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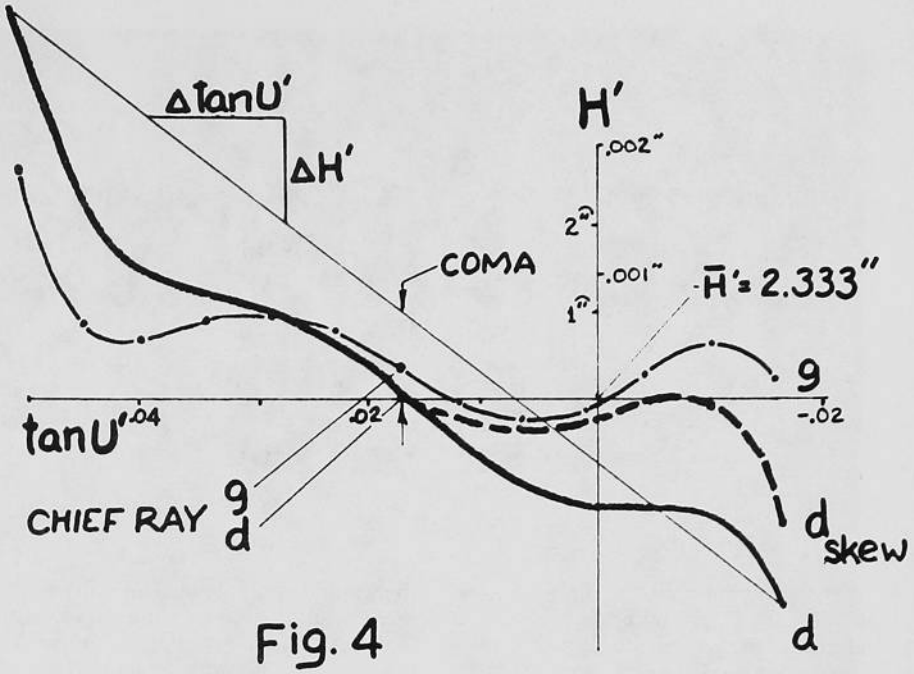


Fig. 4

H'tanU' plot of 1° off-axis image showing zonal spherical, coma, astigmatism, and chromatic (longitudinal + lateral) aberration.

Editor's Note: *Perhaps the most exciting part of raytracing a new or old design is the analysis of the final results which will indicate the final performance of the system. Many of the presently published articles on amateur lens design deal only with axial rays and image formation. Fortunately, or perhaps we can also add unfortunately, it is relatively easy to design an optical system with excellent axial definition with parallel rays coming into the aperture. However, as the observer uses areas off the axis, it is equally important that images be acceptable there also. This is why one is beginning to see programs for amateurs that involve tracing of skew rays that are involved in off-axis image formation.*

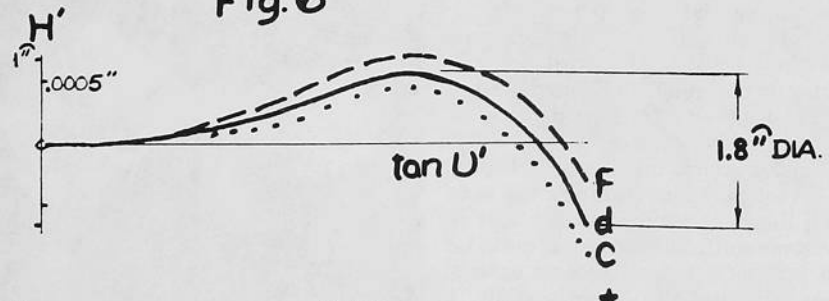
Professional lens designers use several methods of analysis in determining the final performance of a system; however, at this time such an approach is not available to the amateur. Those include: longitudinal spherical aberration (LA'), H'tanU' as outlined in the accompanying article, the optical path differences of rays (OPD) from various locations on the optical system, and finally spot diagrams, which show the locations of many rays in the image plane.

Of all these methods, the last, spot diagrams, is the most difficult for the amateur to handle. It takes more than a simple pocket calculator or microcomputer to handle all the information involved. However, if one has the time and patience (and that, after all, is the advantage of being an amateur), then even if it is done ray by ray, it is possible to plot a meaningful spot diagram.

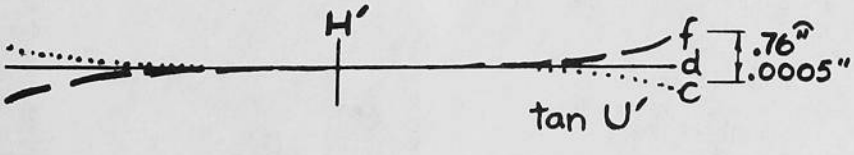
At a later time, TM will present information on the OPD method to go with as we've already done on LA' and H'tanU' analyses of optical systems.

-R.E.C.

Fig. 6

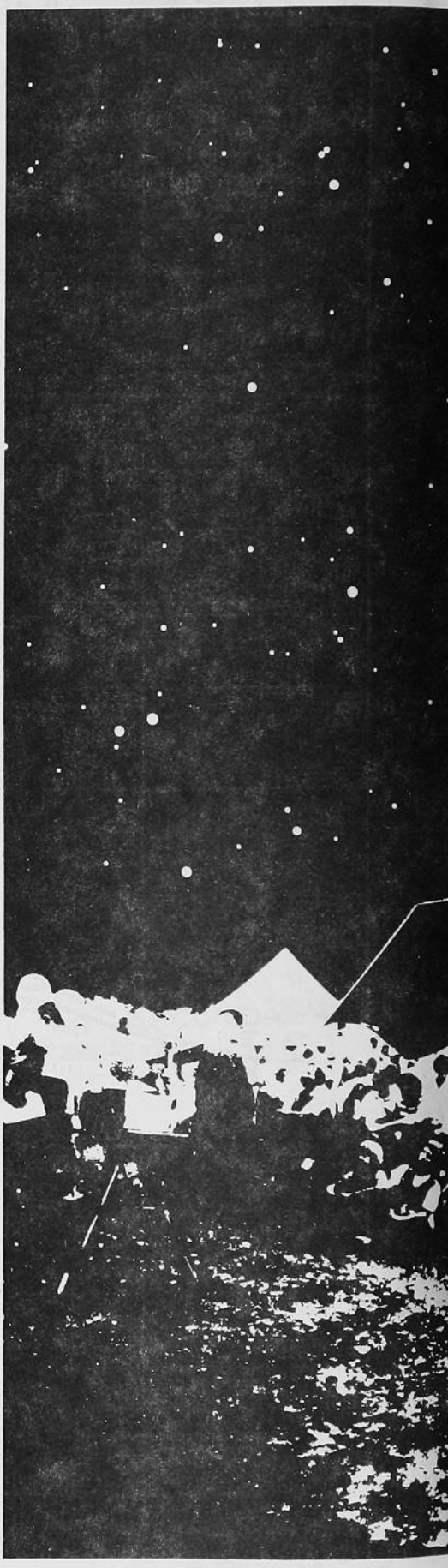


(a) AXIAL IMAGE OF 6" f/23 CASS-MAK*, COLOR CORRECT AT THE PARAXIAL ZONE, NOT THE .8 HT ZONE.
*See TM #14 page 40, fig. 4



(b) SAME, BUT FIGURED FOR d LIGHT NULL.

STELLAFANE 1983



You can't carry a 6″ f/15 refractor — let alone a 6″ f/8 reflector — onto an airplane, so this year Ele and I decided we'd drive to Stellafane in our new red van. It's a drive I hadn't made before, from the flat glacial outwash of southern Wisconsin, the big swamp at the southern end of Lake Michigan — now industrialized as Gary — across the thinly bedded limestones of Indiana, the gently rolling Ohio hills along the southern edge of Lake Erie, then into the ridges of New York State; finally leaving expressways on the last day, at Albany, to connect with winding roads to Burlington, then following winter tourist ski roads to Route 11 leading us, ultimately, to Springfield, Vermont, and Stellafane.

Trucks dominate the tollroads; their average speed is somewhat in excess of 65. I found I tended to fall in behind a truck, usually one carrying a distinctive load — transformers, fork-lift trucks, huge spools of wire, large brightly-painted weldments with no obvious function — then rack up 40 or 50 miles well above our country's national speed limit. We welcomed the rain and thunderstorms we encountered near Cleveland and drove through as we crossed Pennsylvania on the second day — welcome relief from the stifling heat we enduring crossing Indiana.

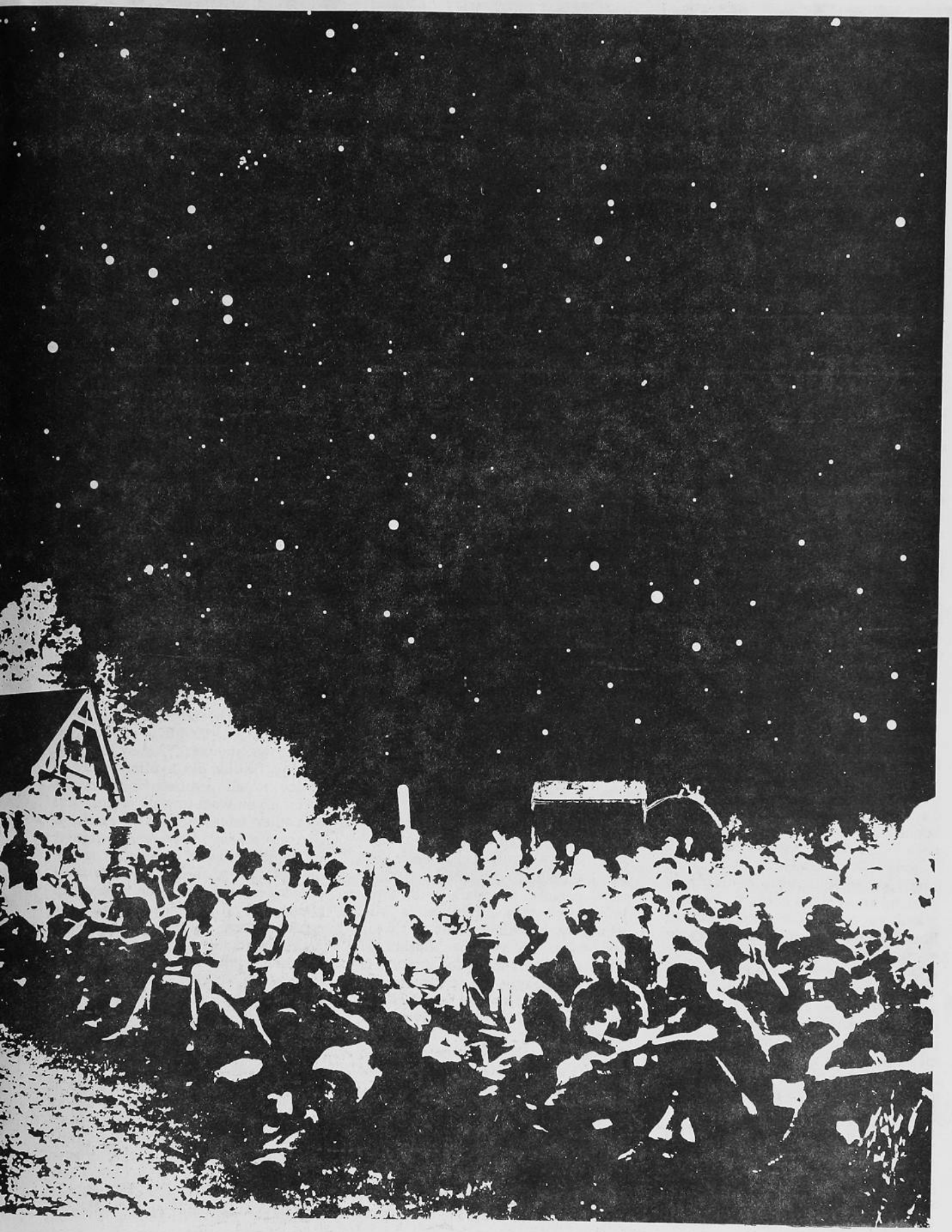
Despite this day of rain, the upper midwest has been, for the most part, dry this year, the acreage planted quite visibly reduced by the PIK program. The diminished numbers of fields of corn, however, contrasted with the abundant roadside stands of cattails, Queen Anne's lace, chicory, black-eyed Susans, and purple loosestrife that beautify midsummer's midwestern North American landscape.

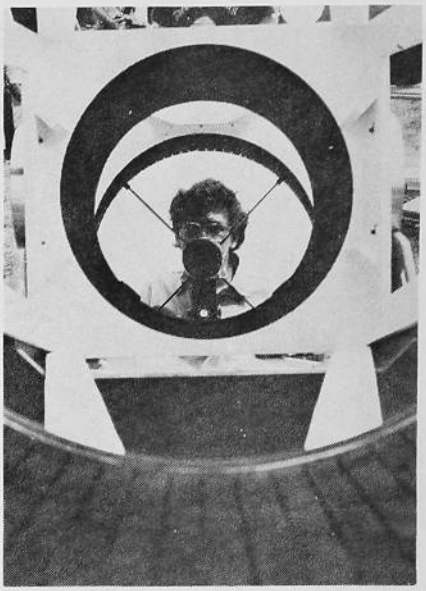
We drove the final mile of dirt road, arriving a little after noon on Friday. Although it was a dull day, it was still muggy and hot. I played the clutch and brake waiting in line on the hill for the registration to move, craning my neck to see what was happening and hoping the guy behind wouldn't pull up too close. He stayed his distance, probably not fully appreciating how new I was to the manual shift. The camping field was already half-filled, multi-colored tents scattered here and there among the throng of vehicles. It looked a lot the same, despite the planting of several acres of Christmas trees that threaten the Stellafanes-as-we-know-them of the future.

Finally we rolled over the hump, snatched our camping permit and registration forms, waved to Dennis di Cicco, and headed off to find our spot this year. Doing anything in the heat was sweaty, and a freshly mowed field always sets off my allergies, so, sneezing, Ele and I hurried through setting up the tent; then I started the van engine again and drove up the road to unload the telescopes.

Walking around the summit of Breezy Hill is tough, but navigating a van over such lumpy ground to a safe spot is awesome stuff. Somebody told me to be quick about it before the next vehicle came up the hill. Thanks. Still, I managed to pull off this feat of driving, unloaded both scopes, backed out, then drove down the hill, parked, walked back up, and started to set them up. The familiar routine of unfolding the refractor tripod legs, bolting the rocker on, and lifting the tube into place calmed me considerably. In fact, I felt good. Once again I was at Stellafane, now 20 years older than I'd been the first time I'd climbed Breezy Hill. Somewhat to my surprise, my two were among the first telescopes there. A few people hung around and watched me set up.

Bringing a 6″ reflector to Stellafane is





The Deep Sky Magazine *crew mugs for the camera: David Levy, Phil Harrington, Walter Scott Houston, Jim Meketa, Glen Chaple, and Richard Berry. Photo by Paul Valleli.*

probably a dumb thing to do. Although a 6″ refractor gets noticed, if for no other reason than standing ten feet tall, small reflectors are a dime-a-dozen. Nonetheless, it's an elegant little telescope and has several nice features, not the least of which is a wooden mirror cell with integral silicone rubber pads which hardly ever needs recollimation.

I went to the evening tent talks, which I've often missed before, because Friday evening was cloudy until quite late. Phil Dombrowski kicked off the evening with, "If someone will hum the 'Space Odyssey' theme music, we'll just go through these slides," and his description of his visit to the STS-7 liftoff which NASA arranged for educators. "They really rolled out the red carpets for us," he said.

Perry Remaklus spoke on Jean Texereau. "My whole life changed one day when, in the Penn Station bookshop, I found a little paperbound book." The book was *How To Make a Telescope*. Because he is now publishing a new edition of this hard-to-find classic (which I know about because I've been asked to write the introduction), Remaklus has now talked to Texereau many times. What has Texereau been up to since he wrote his book? "...Jean Texereau has made a profession of going around and refiguring mirrors and lenses...over 30 major instruments redone...refigured the McDonald 82″ to an overall ⅛th-wave...the optical shop of Paris Observatory closed in 1977; since then he's been on loan to other institutions."

Then George Keene showed slides of New Zealand, girls, koalas, girls, Indonesia, girls, a solar eclipse, girls...the pools, he said, had good scenery.

Dennis di Cicco spoke on his tiny backyard observatory. He started out with big plans (don't we all), but then reality set in. "What happened," he said, "is I came up with an alternative...it took two weeks to build — one full day on each weekend plus some evenings." He started with a steel pipe pier 12″ in diameter and 8′ long, and built the rest out of 4x8 waferboard. "It's got a real sophisticated foundation — I sharpened some 2x4s and sledgehammered 'em into the ground." Dennis likes his new observatory: "It's kinda small, but I can sit at the eyepiece and reach every single item in the observatory."

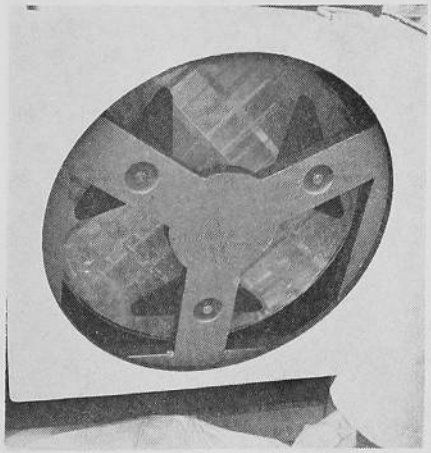
"Cheap Astronomy" was next — astronomy for an annual investment of $15. What Jan Roemer was really talking about is sketching at the telescope. She uses an old 8″ f/8 Criterion remounted à la Dobson, and her $15 goes for black pastel paper and pastel pencils. She starts with three dominant stars, then adds the nebulosity, and finally fills in all the field stars. To get the illusion of nebulosity, she applies the pastel to a sponge, then rubs the sponge on the paper. "Go back several times and put down more detail," she said. Her M-42 drawing, made with a friend's 17″ Dobsonian, took here three weeks (on and off) to complete, but it drew the applause of the crowd.

Alan French had some useful advice on finishing cardboard tubes. Getting the wax coating off is tricky, but the idea, if I understood him correctly, is to peel off the thin outer layer starting from the wrong (overlapped) end and work slowly up the tube. The inside coating peels easily, he said. French also uses a "tube lathe" to fill windings, bumps, hickies, and dents in the tube with auto body filler. The tubes need end rings, so he has built a wood circle cutter by mounting a router upside-down inside a box. "The easiest way to finish a tube," he added, "is to cover it with plastic, vinyl, or cloth, such as a starry bedsheet, and Scotchgard it." I invited him to write an article for TM, and he said he would.

I was tired, so I covered the scopes for the night and joined Ele in the van. One advantage to sleeping off the ground in a truck is that my allergies did not attack with quite their usual vigor. I could still breathe.

But morning began much too early. At 9 am, I went up the hill to uncover the telescopes and ready them for the judging. I would like to offer a word of advice to all prospective Stellafane goers: if you want to walk around and see other telescopes, *don't exhibit a telescope yourself.* Between the time it was announced over the speaker system that exhibitors should be near their telescopes, and the time I gave up waiting for all 13 judges to initial the exhibitor tag, something like seven hours passed. (Some of the judges forgot to initial exhibitor tags, which messed up my chance to examine all the telescopes on the hill.) Luckily, Ele brought me some food at noon and again in the evening.

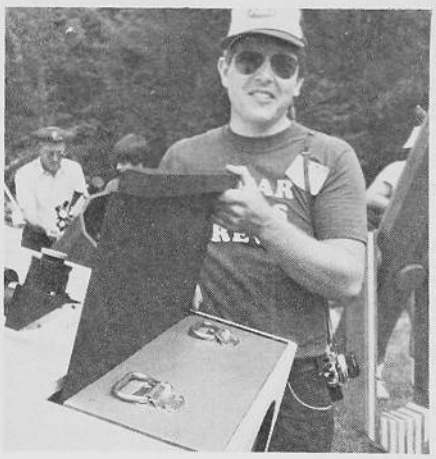
Around noon, David Levy appeared, ashen-faced, and told me that he had just received a phone call from Tucson informing him that Bart Bok, the Milky Way astronomer, had died of a heart attack. David is Bok's friend and biographer, the man Bok had entrusted to put his life story into words. There was nothing I could say. Bok and I had met by chance some eight weeks earlier

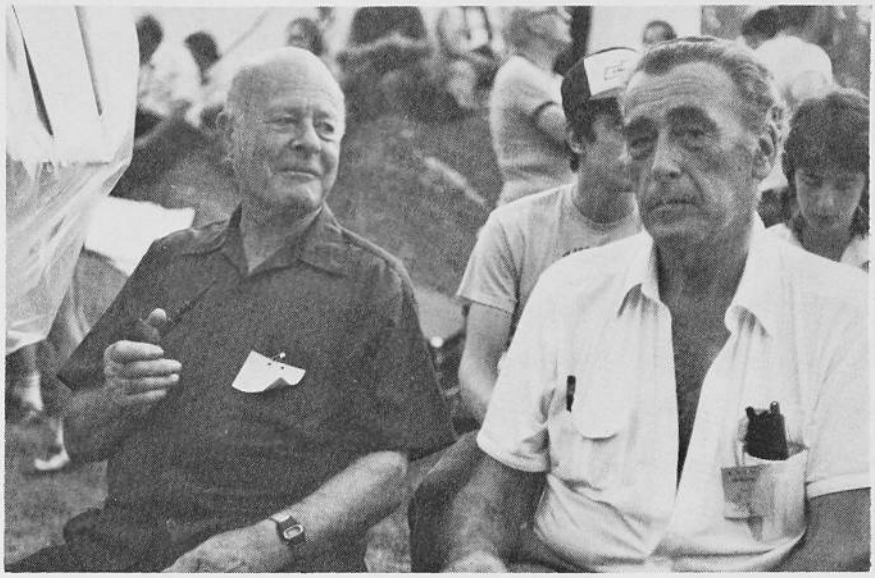


John Vogt brought the largest telescope ever to appear at Stellafane — a 24" open-tube Dobsonian reflector. Note that side panels are cut from a single piece of plywood, thereby eliminating joints.

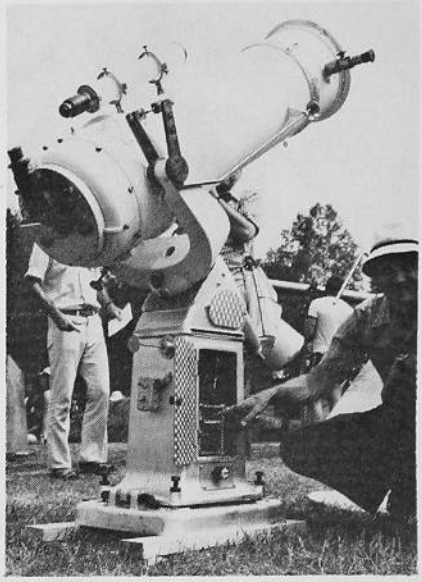
John Vogt demonstrates the dark slide for his mirror cell.

The back of Vogt's egg-crate mirror and its cell.





Alan MacIntosh and Dr. Frank Barr of the Mak Club, and pioneer makers of compact, high performance telescopes, wait for the evening talks to begin.



Duane Niehaus and his Porter-designed 12" Cassegrain site testing reflector. Note typical Porter touches — massive fork, tapered RA bearing, exterior contouring.

in the Singapore International Airport, of all unlikely places, while we were both on the way back from the Indonesian solar eclipse. He had cheerfully invited me for a drink — very warm, alive, and vital — and joked about his heart condition while we talked.

During the day it rained off and on. I had a big supply of giant leaf bags, so I managed to keep both of my telescopes reasonably dry. Other people had huge plastic drop sheets which are considerably better than leaf bags and more versatile. At one point, I spent twenty minutes under Al Nagler's 8" plastic-draped folded refractor while a cloudburst soaked everything that wasn't covered.

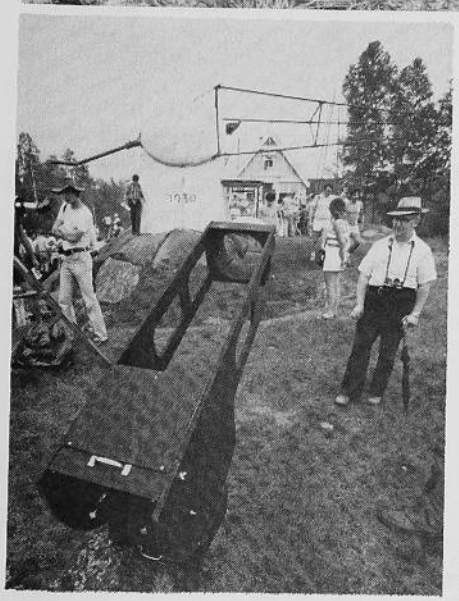
Meanwhile, the whole show took on a comic air because reporters from Time-Life's *Discover* magazine (via Dennis Overbye, who's gotten into big-time journalism) were running around taking pictures and interviewing people. One of them looked at the refractor and breathlessly asked me, "How long have you been interested in astronomy?" I told him, "Since I was about thirteen," which seemed to disappoint him somehow. He bustled off and probably kept asking people how long they'd been interested in astronomy until somebody gave him the answer he wanted to hear. Dennis told me that this was his first Stellafane, and seemed rather bemused by all the fanatics.

Despite exhibiting, I did get a chance to look at some telescopes. John Vogt's 24-incher was the largest telescope ever shown at Stellafane, now topping Roger Tuthill's record 20" and Steve Dodson's 22". Vogt's telescope featured an egg-crate primary mirror which he ground and figured himself. Image quality was excellent. One of the cleverer things he did was provide a slide-in mirror cover. In addition, the whole mirror cell slides out and can be carried separately. Tube sides were cut from a single sheet of plywood, so there was none of that slop in the truss structure that sometimes occurs where parts are joined.

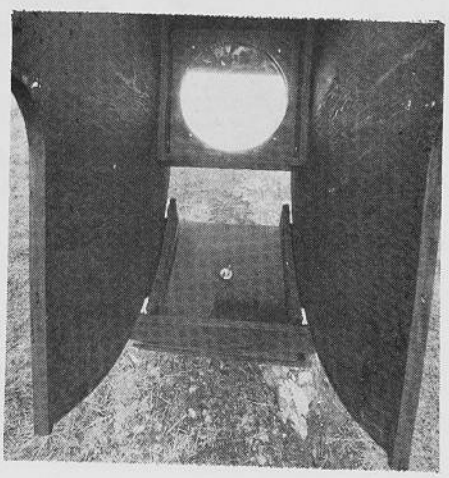
Duane Niehaus of Tucson showed a 12" Porter site-test Cassegrain which he is reconditioning. It was made in 1936 and finished in 1937 by Harold Lower's group in LA, amateur-built from the same patterns as Porter's site-test telescopes for the 200". Niehaus intends to restore it to its original condition, including rebuilding the weight-driven drive. Before he got it, Niehaus said the telescope had resided in California, Texas, Florida, Pennsylvania, Indiana, and now Arizona.

Another unique telescope, although unique in a completely different way, was Chuck Thompson's 12.5" f/6.6 um, er, uh — reflecting telescope. Based on Dobsonian principles, it does away with the customary differentiation between mount and tube. The instrument consists of two lower-case "d" shaped plywood side pieces which ride on a rotating table. Four bolts hold the upper and lower ends to the side pieces, and the instrument is knocked down for transport. The prototype was a bit shaky and didn't move too smoothly, but the idea deserves further exploration.

Plastic, plastic everywhere! Painter's plastic drop cloths are great for rainy telescope maker's meetings.



Chuck Thompson's "Thompsonian" reflector demonstrates considerable promise, so should interest innovators in exploring the field of ultra-portable, large-aperture instruments. Needed are greater stability and smoother motion, particularly in elevation.



An "inside view" of Thompson's 12.5" reflector, showing the mirror, its cell, the side pieces, and the rotating base.

This year, tallying the judges' scores was done with an Osborne computer.

Judges consult, mutter, shake their heads, write inscrutable things on clipboards, then move on. Dennis di Cicco, ATMs of Boston, carries camera bag.

Chuck hails from Elgin, IL, and also showed the instrument at this year's AstroFest. If the design catches on, we'll be obliged to call it the "Thompsonian."

Finally, one of the prize winners was a first telescope: a massive, machined reflector finished just days before the meeting by David Astafan of New Hartford, NY. Weighing in at some 550 pounds, this 12.5" f/6 Newtonian reflector had obviously taken hundreds of hours of work. Details such as the Acme-threaded declination shaft were well done. He also made the setting circles and scribed them. Both axes. Pillow blocks are supported on ⅝" thick aluminum plate in declination, and ½" steel in R.A. Astafan said his "...non-complaining wife has been a blessing — and we had a baby on Friday." He said this on Saturday.

After having a rather rushed dinner of chicken with "bob-a-que" sauce on it, baked beans, then gulping down enough liquid to replenish what I'd lost during the long, sweaty day, I was glad to sit quietly on the slightly soggy ground for the evening talks. If you didn't already know, things at Stellafane are changing. The camping field which is vital to accommodating 1,000+ telescope makers, belongs to someone else. He has always let the Springfield Telescope Makers mow it flat to use it for a campground in the past. But this year he's started to plant Christmas trees on it, and since those can't be mowed down, the camping area and, with it, Stellafane-as-we-know-it could vanish.

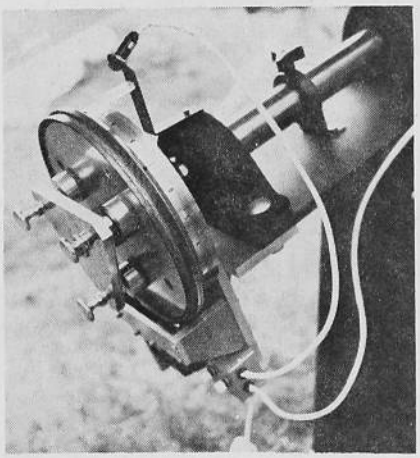
The club has begun the big job of altering the summit of Breezy Hill behind the clubhouse, but they will need thousands of dollars to dynamite the recalcitrant rock into some semblance of flatness. In a short, heartfelt speech, Roger Tuthill said, "I came to Stellafane more than twenty years ago. I hope to come for another twenty years. For me, it is almost a religious experience. When I hear of difficulties at Stellafane, I get very troubled." Roger has donated $100, an amount any of us can afford, toward an "SOS" (Survival of Stellafane) Fund. "I owe a great deal to Stellafane," he said; "I would not be enjoying my current lifestyle if it were not for this place and people I have met here."

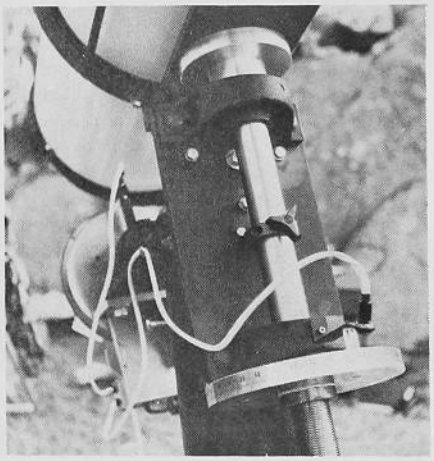
Those of us who love Stellafane, said Roger, "can never repay, even in a small way, those people we have met here who have helped and encouraged us in astronomy." After that they held a drawing for door prize telescopes supplied by Celestron, Meade, and Bushnell. The first winner picked the Meade scope; the second winner, Celestron; and the last one took the Bushnell. If you are interested in helping Stellafane survive the present crisis, contact the Springfield club's president, George Scotten, 61 Reservoir Rd., Springfield, VT 05156. At present, the club is still looking into what to do.

Scotty Houston's Shadowgram addressed the age-old question of what makes Stellafane so good. First off, he said, "it started slowly and it grew slowly, so [the people who run it] learned how to solve the problems." And by "going slow and getting a little bigger each year, the people [who came to it] got to trust us. They showed an amazing tendency to come back." So fifty years after it started, "instead of 35, we have several thousand people. But

Photo by David Healy.

David Astafan, still quite surprized to have won a prize, stands beside the telescope he built.





This is the polar axis, drive, and circle assembly of David Astafan's 12" reflector. Note the adjustable slip clutch and finely-divided circle. The small collar around the shaft adds needed friction.

Breezy Hill was ablaze with red flashlights on Saturday night. Exposure: 15 minutes at f/2.8 on Kodacolor 1000, by David Healy.

the things on the wall are pretty much the same." But, he added, there's a new reason for coming to Stellafane now: "For people from New Jersey, this is their one chance each year to see a star!"

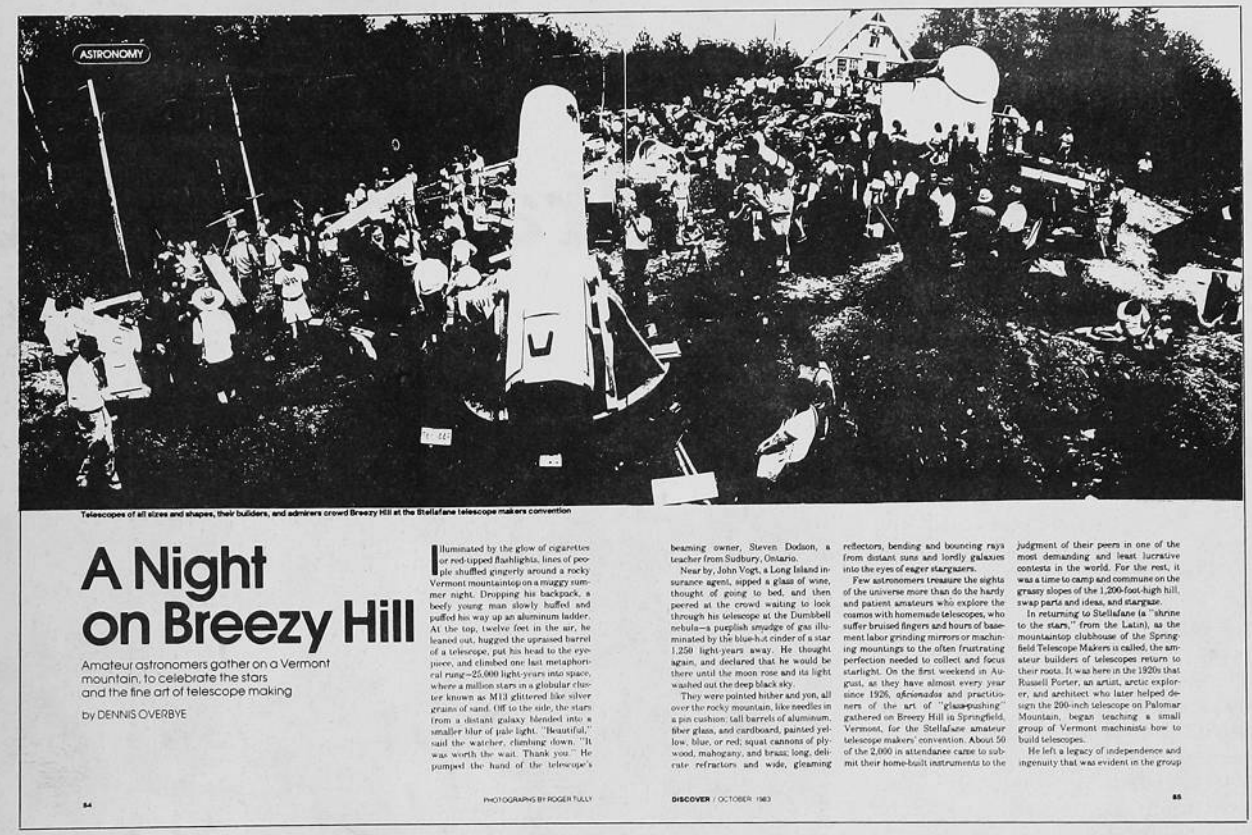
And that special ingredient? "I've just come back from Riverside, the Texas Star Party, and the Astronomical League Convention. None have the depth of humanity — it will develop in a quarter of a century."

He concluded with a story, "Fred Lossing had a heart attack, and the doctor said 'NO!'" So he wrote Scotty a letter saying he couldn't come. "'I know I can't climb the hill, but that can be taken care of. I could ride to the top. And I know I can't sleep in a van, but that can be taken care of. I could sleep in a motel. But that wild, blinding excitement — that can't be taken care of.'"

The keynote speaker was Paul Horowitz, speaking on his SETI

Roger Sinnott, of Cosmic Computer Works, and Mary Ashman of Bloomfield Hills, MI pause for a moment in their examination of telescopes.

John Briggs of Westport Point collects and shows Alvan Clark refractors. I was impressed with the simplicity and elegance of the small equatorial head on this 4" refractor.



ASTRONOMY

Telescopes of all sizes and shapes, their builders, and admirers crowd Breezy Hill at the Stellafane telescope makers convention

A Night on Breezy Hill

Amateur astronomers gather on a Vermont mountain, to celebrate the stars and the fine art of telescope making

by DENNIS OVERBYE

Illuminated by the glow of cigarettes or red-tipped flashlights, lines of people shuffled gingerly around a rocky Vermont mountaintop on a muggy summer night. Dropping his backpack, a beefy young man slowly huffed and puffed his way up an aluminum ladder. At the top, twelve feet in the air, he leaned out, hugged the upraised barrel of a telescope, put his head to the eyepiece, and climbed one last metaphorical rung—25,000 light-years into space, where a million stars in a globular cluster known as M13 glittered like silver grains of sand. Off to the side, the stars from a distant galaxy blended into a smaller blur of pale light. "Beautiful," said the watcher, climbing down. "It was worth the wait. Thank you." He pumped the hand of the telescope's beaming owner, Steven Dodson, a teacher from Sudbury, Ontario.

Near by, John Vogt, a Long Island insurance agent, sipped a glass of wine, thought of going to bed, and then peered at the crowd waiting to look through his telescope at the Dumbbell nebula—a purplish smudge of gas illuminated by the blue-hot cinder of a star 1,250 light-years away. He thought again, and declared that he would be there until the moon rose and its light washed out the deep black sky.

They were pointed hither and yon, all over the rocky mountain, like needles in a pin cushion: tall barrels of aluminum, fiber glass, and cardboard, painted yellow, blue, or red; squat cannons of plywood, mahogany, and brass; long, delicate refractors and wide, gleaming reflectors, bending and bouncing rays from distant suns and lordly galaxies into the eyes of eager stargazers.

Few astronomers treasure the sights of the universe more than do the hardy and patient amateurs who explore the cosmos with homemade telescopes, who suffer bruised fingers and hours of basement labor grinding mirrors or machining mountings to the often frustrating perfection needed to collect and focus starlight. On the first weekend in August, as they have almost every year since 1926, *aficionados* and practitioners of the art of "glass-pushing" gathered on Breezy Hill in Springfield, Vermont, for the Stellafane amateur telescope makers' convention. About 50 of the 2,000 in attendance came to submit their home-built instruments to the judgment of their peers in one of the most demanding and least lucrative contests in the world. For the rest, it was a time to camp and commune on the grassy slopes of the 1,200-foot-high hill, swap parts and ideas, and stargaze.

In returning to Stellafane (a "shrine to the stars," from the Latin), as the mountaintop clubhouse of the Springfield Telescope Makers is called, the amateur builders of telescopes return to their roots. It was here in the 1920s that Russell Porter, an artist, arctic explorer, and architect who later helped design the 200-inch telescope on Palomar Mountain, began teaching a small group of Vermont machinists how to build telescopes.

He left a legacy of independence and ingenuity that was evident in the group

PHOTOGRAPHS BY ROGER TULLY

Discover*'s article brought Stellafane to the masses.*

program. As he spoke, the overcast thinned and broke, and a few stars twinkled. Jupiter appeared low in the southwest. Then the Milky Way broke through. Horowitz concluded, the lights were shut off, and observing began. I was there 'til 3 am showing people Epsilon Bootis and Epsilon Lyrae cleanly resolved with the refractor. I was so busy showing people, in fact, that I didn't get enough chance to look through Mattei's 6″ Schupmann telescope until about 1:30 am, but the seeing had gone soft on us. I never had a chance to see Al Nagler's or Roland Christen's latest creations, but I did manage a minute with John Vogt's 24″ Dobsonian (he deserves congratulations on his fine mirror) and Steve Dodson's skyscraping 22″. Finally, so tired I could barely walk down the hill, I rolled into my sleeping bag and passed out.

The next day, after negotiating the hill with the van again and loading the telescopes, and breakfast at the Idlenot, Ele and I headed over to Francestown, New Hampshire to visit my brother Steve, sister-in-law Pam, and niece and nephew Krista and Justin. That afternoon, the sky cleared while we were swimming in a nearby reservoir, so in the evening we unpacked the refractor again — but the magnificent dark skies we hoped for were lit by a bright aurora that extended well south of the zenith. Several days later, in the back yard of my parents' home in Stamford, Connecticut, we set it up again beside the remains of the yoke that carried my 12″ reflector between 1962 and 1967, and showed my father and mother Jupiter and a few bright doubles and nebulae. Later that night, after everyone else had gone to bed, I observed from that familiar site until the wee hours.

— *Richard Berry*

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More on Hydraulic Drive

After my first hydraulic nested-corner equatorial platform (TM#17, page 6), I've gone on to build an improved Mark II platform for the same 17″ Dobsonian reflector. The Mark II model uses a short but massive hinge at the east side in place of the cumbersome nested box arrangement. In using such a short hinge, though, I found it necessary to attach a stabilizing wheel to the platform adjacent to the head of the jack. This wheel runs on an inclined plane of 1″ x 1″ angle iron smoothed on a belt sander.

In the center of the platform, on the south edge, is the adapted automobile brake cylinder which provides the declination adjustment (of a sort) as suggested in the article in TM#17. A finely-threaded ⅛″ diameter shaft screws into place where the hydraulic line normally goes. As the shaft is screwed into the cylinder, the piston is displaced upward, thus tilting the ground board of the telescope northward. This provides an extremely fine adjustment.

I've also made the platform portable. As the photos show, detachable wheels make the platform a reasonably compact package.

One design feature still needs attention. Because the hinge is relatively short, the platform tends to rock a little, if pushed, in the north/south direction. This motion was negligible in the long-hinged nested-box arrangement because the angle subtended by the hinge to the head of the jack was large (almost 50°). But with this new design, the angle is less than 15°, so any flexibility or play in the hinge results in detectable vibration.

The solution to this lies in a proposed Mark III model with two parallel ramps on the north-west and south-west corners, separated from each other by their distance to the hinge, thus giving the ideal angle of 60° for a three-point suspension system. I haven't tried this with a working model yet.

I wonder what the Mark IV will look like?

Bob Barclay
3609 Downpatrick Road
Ottawa, Ontario, K1V 9P4

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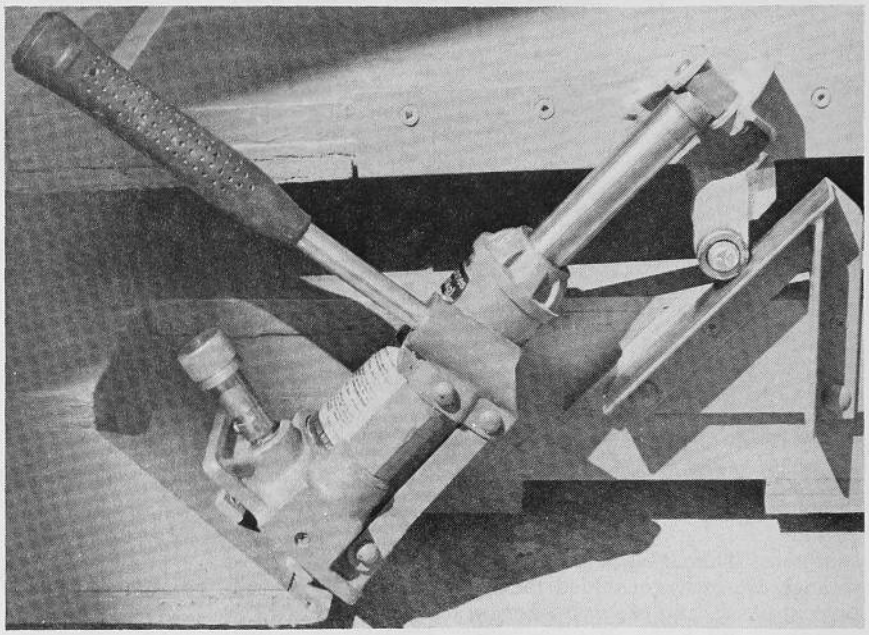
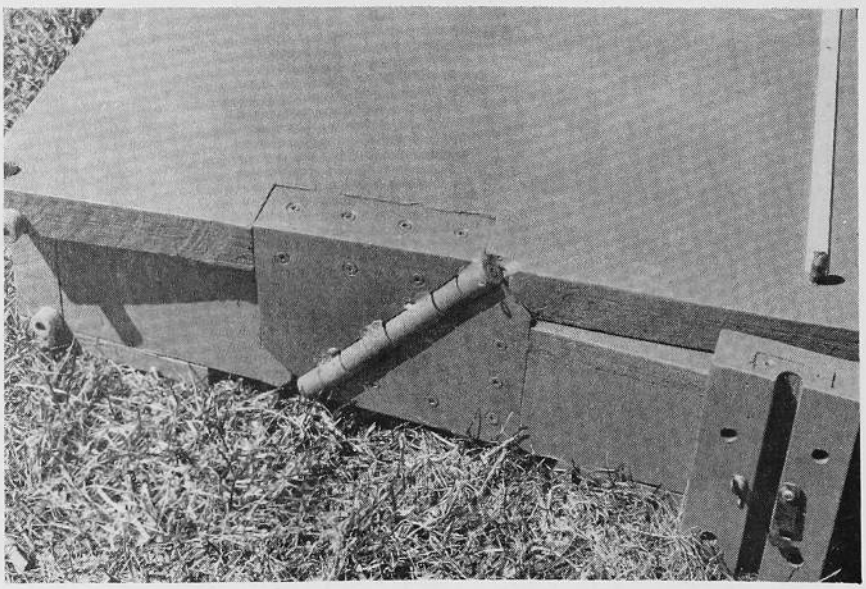
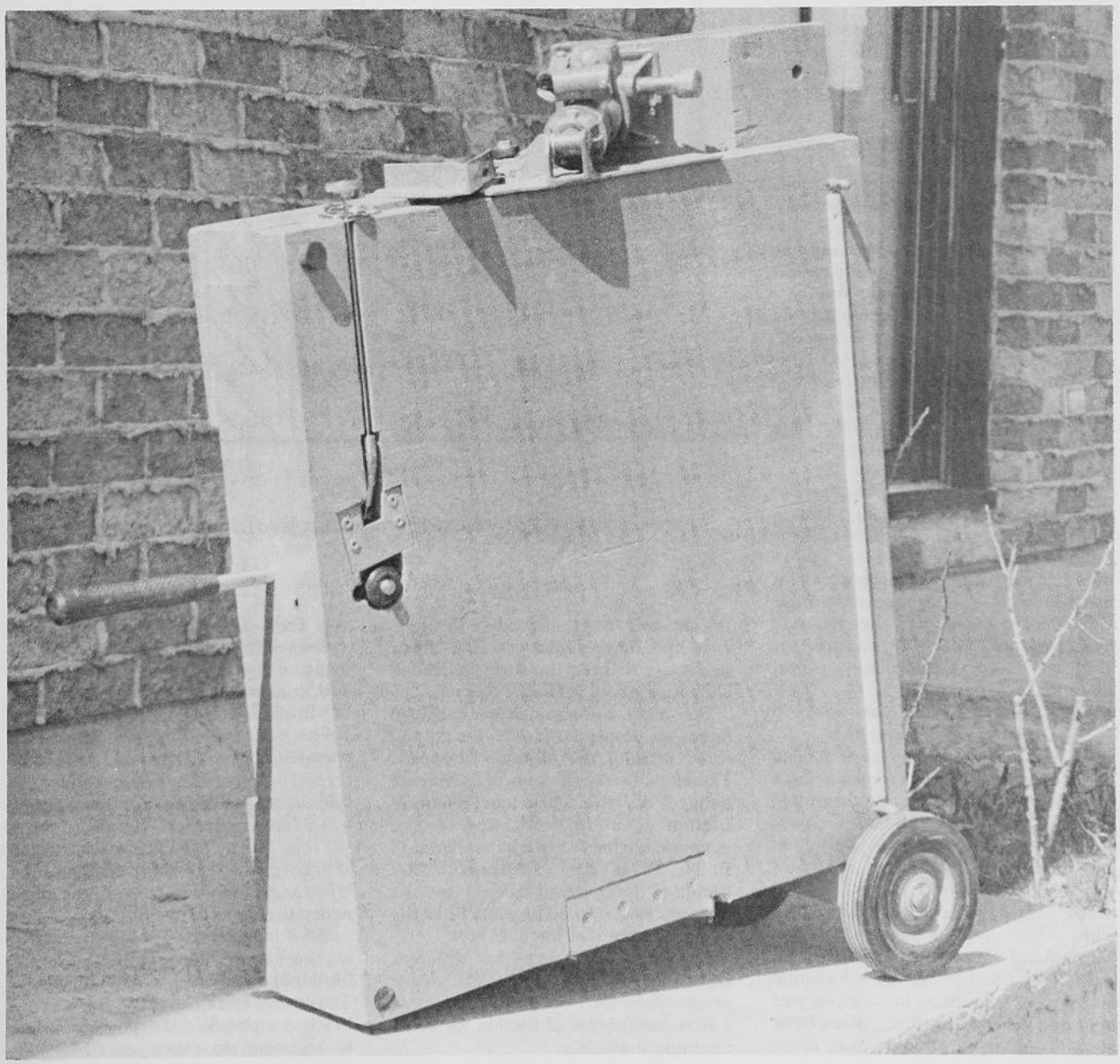




Equatorial Platforms



Teflon Telescope Bearings

Purpose

The purpose of this project is to investigate the frictional properties of various bearings using T.F.E. Teflon as the base material, and to determine what frictional properties make Teflon telescope bearings desirable.

Introduction

A telescope mounting must be stable, rigid, and able to be pointed accurately. The Dobsonian design is a simple, low-cost alt-azimuth telescope mounting using plywood construction and simple two-piece Teflon and plastic laminate bearings. It is manually pointed so the bearings must be able to move smoothly without sticking or jumping, yet have enough friction that when the telescope is bumped or buffeted by a gust of wind, it doesn't move. The bearings must wear well and, for ease of construction, not require close tolerance parts.

My six-inch Dobsonian telescope was inspired by a telescope making session held at the 1981 National Astronomical League Convention where Teflon bearings were highly recommended for use in Dobsonian telescope mountings. I decided to investigate the frictional properties that make Teflon bearings work well, and to determine the best material for use with it.

Definition of Friction and Coefficient of Friction

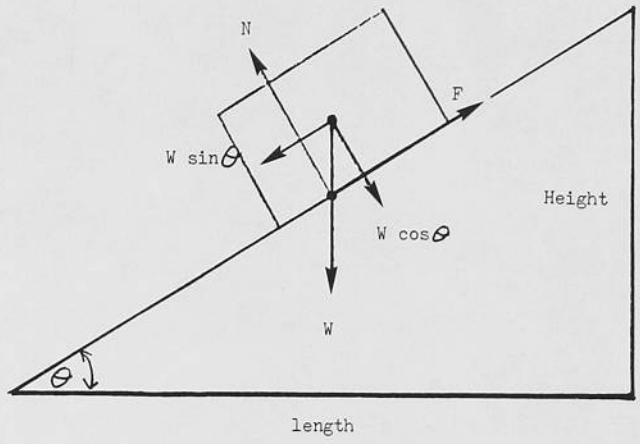
When one body slides on a second body, each body exerts a frictional force on the other, parallel to their contacting surfaces. These frictional forces oppose the motion of the bodies. The origin of the frictional forces is not well understood. However, the frictional properties of surfaces may be studied without having this detailed knowledge.

Frictional forces also exist without motion of the bodies. Two frictional forces may be defined for a given pair of materials: one a static frictional force equal to the force attempting to move the surfaces, and the second a dynamic frictional force equal to the force necessary to keep the surfaces sliding with a constant velocity.

For most surfaces, these frictional forces are proportional to N, the normal force holding the surfaces together. Therefore, two coefficients of friction are defined, U_s the static coefficient of friction equal to F_s/N, and U_d the dynamic coefficient of friction equal to F_d/N. F_s is the maximum static frictional force reached just as the surfaces begin to slide, and F_d is the dynamic frictional force.

U_d may be different for different velocities. In most materials, U_s is greater than U_d. For comparison, table 1 lists coefficients of friction for some common materials.

FIGURE 1.



INCLINED PLANE METHOD OF MEASURING COEFFICIENT OF FRICTION

Experimental Technique

An inclined plane method was used to measure the coefficients of friction. A bob consisting of a 2½" square of ¾"-thick plywood had three ½" square Teflon pads nailed to its bottom in a triangular pattern. The nail heads were recessed below the Teflon surface. A cylindrical steel weight 2½" in diameter was added to give a total bob weight of 0.99 Kg. The inclined plane was covered with the material being tested, and the bob was allowed to slide down the plane under the force of gravity.

Referring to figure 1, the forces acting on the bob are its weight W and the frictional forces of the inclined plane. The normal force N holding the surfaces together equals W cos θ. Just as the bob is beginning to move, or when it is

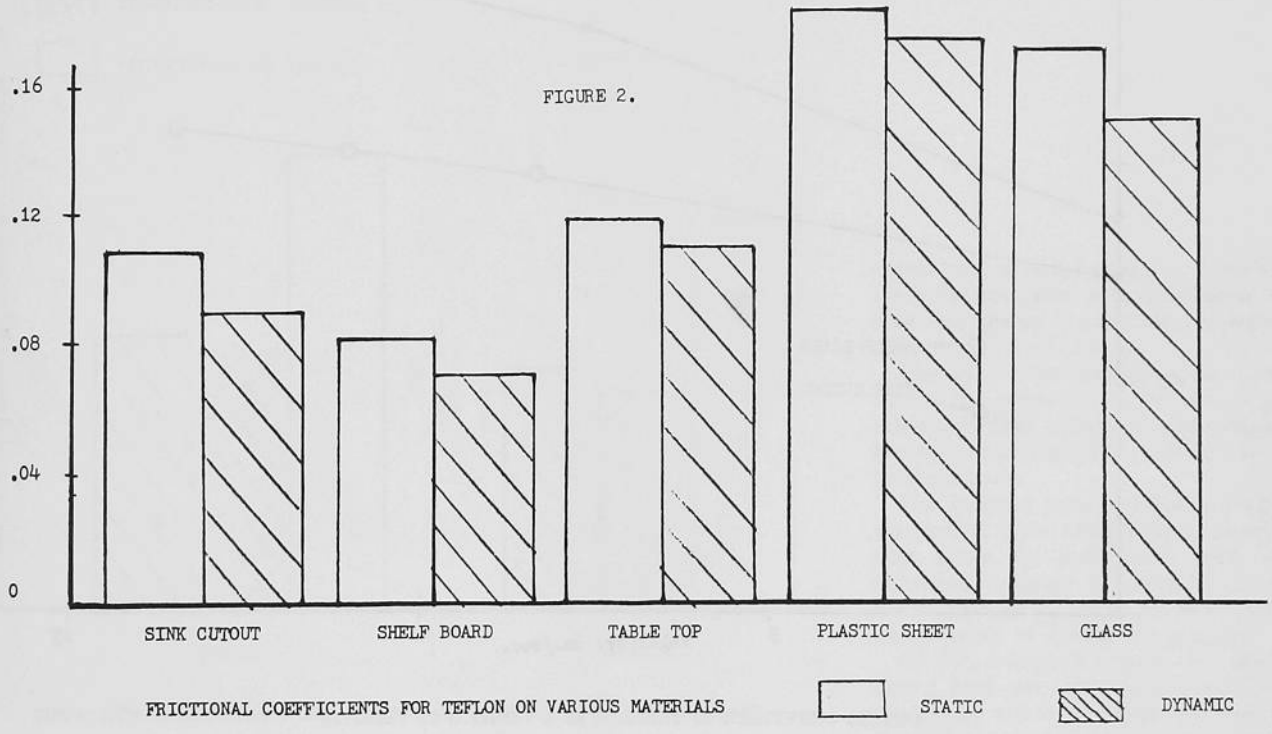


FIGURE 2.

FRICTIONAL COEFFICIENTS FOR TEFLON ON VARIOUS MATERIALS

moving with constant velocity, the frictional force F equals W sin θ. Therefore the coefficient of friction:

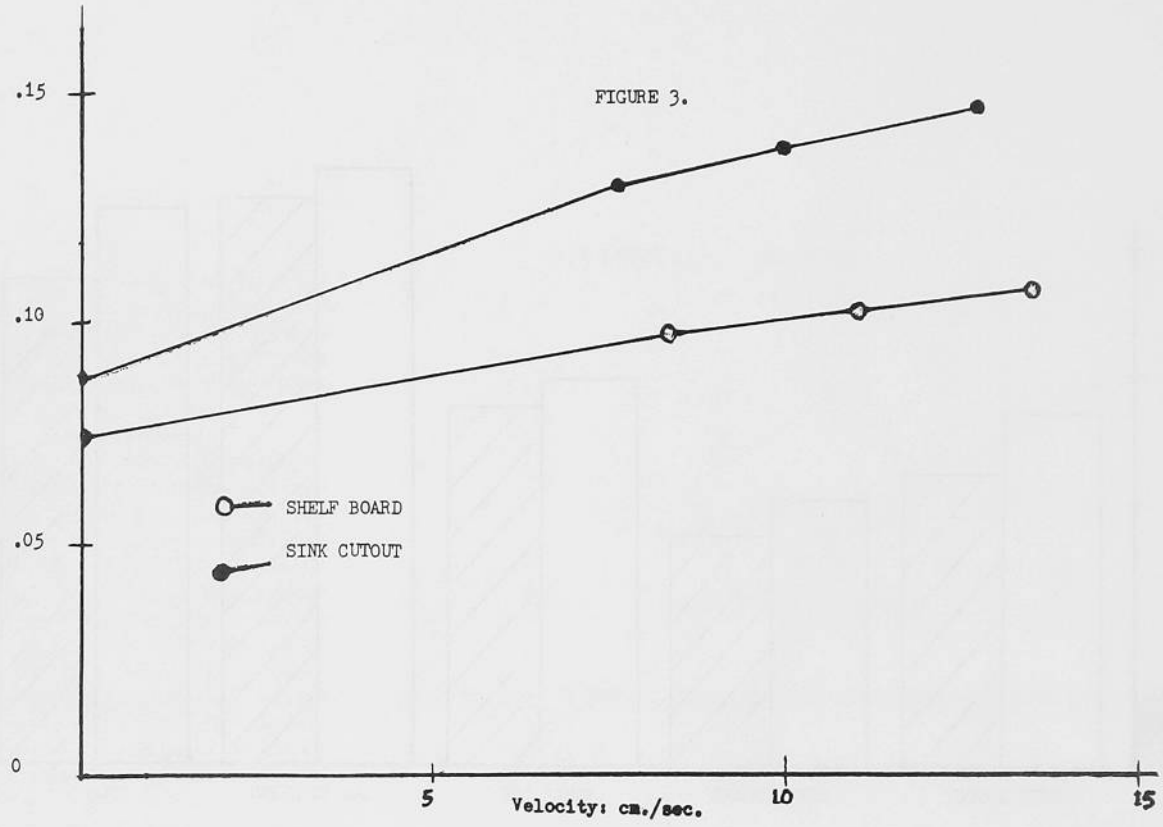
$U = F/N$
$= W \sin \theta / W \cos \theta$
$= \tan \theta$
$= H/L,$

where H equals the height at the end of the inclined plane and L equals the length along the base of the inclined plane.

To obtain the static coefficient of friction, the inclined plane was slowly raised using a $\frac{3}{8}''$ x 16 threaded screw, and the height H for the condition where the bob just started moving was recorded. To obtain the dynamic coefficient of friction, the minimum height H for the condition where a moving bob would just continue to move

MATERIALS	STATIC U_S	DYNAMIC U_D
Steel on Steel	0.74	0.57
Aluminum on Steel	0.61	0.47
Copper on Steel	0.53	0.36
Brass on Steel	0.51	0.44
Zinc on Cast Iron	0.85	0.21
Copper on Cast Iron	1.05	0.29
Glass on Glass	0.94	0.40
Copper on Glass	0.68	0.53

TABLE 1.



DYNAMIC COEFFICIENT OF FRICTION AS A FUNCTION OF VELOCITY

was recorded.

It was noticed that with several materials at heights greater than the minimum height, the bob appeared to accelerate and reach a constant velocity. This was checked by timing the bob between three equidistant points. The velocity was constant since the two travel times were equal. This allowed measurement of the dynamic coefficient of friction as a function of velocity.

Heights and lengths were measured to the nearest millimeter. The same bob was used for all measurements. Before and after each new material, the bob was checked with a standard material to see if changes had occurred due to wear on the bob. Three trials were run with each material and the lowest heights were used since the lower values should represent an uncontaminated surface. Larger values indicate dirt or grit between the surfaces.

Five materials used were:

- ⅛″ thick window glass,
- filled phenolic shelf board,
- melamine-formaldehyde sink cutout with a textured surface,
- melamine-formaldehyde table top with a smooth surface,
- and ⅛″ thick acrylic plastic sheet.

The Teflon bearing material was ⅛″ thick T.F.E. fluorocarbon resin manufactured by Du Pont.

An additional measurement was made on the completed telescope bearing. A postage scale was used to measure the force necessary to rotate the telescope from one end of its tube. The distance from this point to the bearing pivot point and the radius of the Teflon bearing were measured and used to calculate the effective frictional force at the bearing.

The Teflon bearing consisted of three 2″ x 1½″ Teflon pads equally spaced about a 4½″ radius circle. A total weight of 26 pounds was carried by the bearing.

The effective frictional force is:

$$F = (R/r)\, f$$

where f equals the force at the end of the tube, R is the distance from the tube end to the pivot point, and r is the bearing radius. The effective coefficient of friction was calculated by dividing F by the total weight, 26 pounds.

Results

Figures 2, 3, and 4 summarize the experimental results. Figure 2 gives the

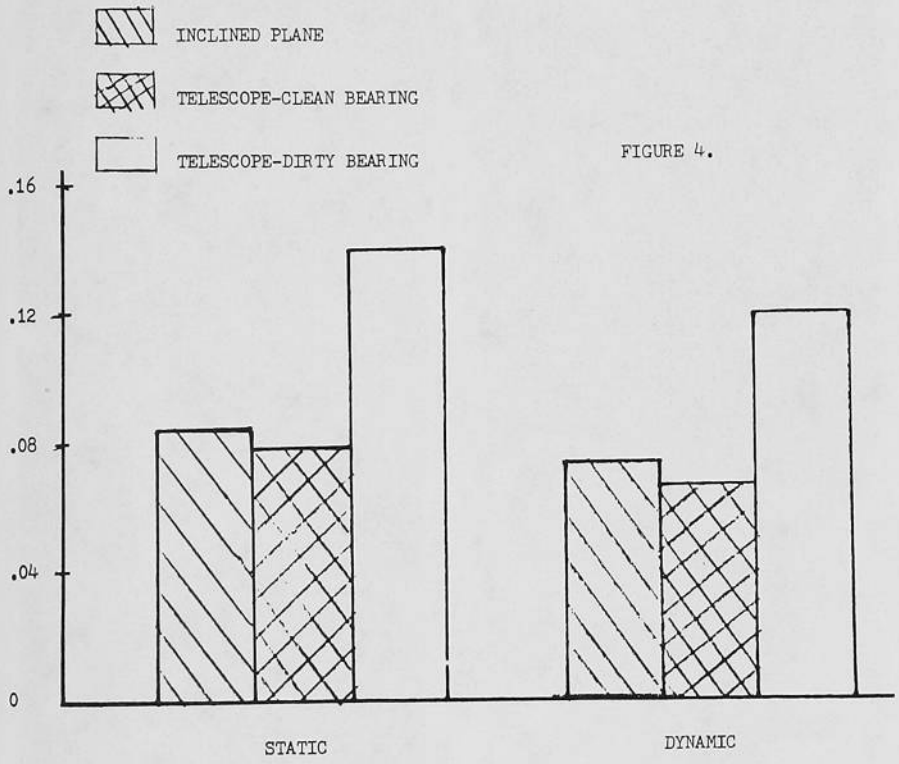


FIGURE 4.

COMPARISON OF FRICTIONAL COEFFICIENTS ON TELESCOPE AND INCLINED PLANE

static and dynamic frictional coefficients for the five materials tested. The dynamic value given is for low velocities. This value is most suitable for use with telescopes because telescopes track slow-moving objects. Teflon on the plastic sheet had the highest coefficient of friction and Teflon on the shelf board had the lowest. Teflon on shelf board had the smallest change in the coefficients of friction from static to dynamic and Teflon on glass had the largest.

Figure 3 plots dynamic frictional coefficients as a function of velocity. The dynamic frictional coefficient increases with velocity in the range measured. The shelf board plotted out as a straight line.

Figure 4 compares frictional coefficients of shelf board as measured by the inclined plane method and as measured in the actual telescope bearing. Note that after two months use, frictional coefficients were greater due to dirt.

Conclusions

Comparisons of frictional coefficients of conventional materials and frictional coefficients of Teflon in table 1 and figure 2 show that Teflon bearings have a special quality. This quality is that the static and dynamic frictional coefficients are virtually identical. This means that Teflon bearings are able to smoothly make the transition from stopped to moving without sticking or jumping, and allow precise positioning of an object in the telescope field. A material with a sudden decrease in frictional coefficient would jump or jerk, because as it breaks loose the force present is much greater than that needed to overcome the lower dynamic frictional force.

The value of the coefficient of friction should be around .10 for use in a telescope. This allows ease of motion but not so easy that the telescope won't hold position.

The inclined plane method worked very well. It doesn't require force gauges that could be inaccurate, and as reference to figure 4 shows, it gives results that agree closely with the actual performance of Teflon in a bearing.

Of the materials tested, the shelf board had the best combination of properties and was selected for use in the Dobsonian telescope I built. I highly recommend the Dobsonian telescope design for its clever use of the unique properties of Teflon bearings. I am able to easily center objects in the telescope at magnifications as high as 200x, and find the mount stable, rigid, and easy to use.

Acknowledgements

I would like to acknowledge my parents for all of their help and support in this project, and special thanks to Mr. Donald Tuttle, Director of the Elgin Planetarium, for his help in obtaining a mirror and tool used for the telescope's primary mirror.

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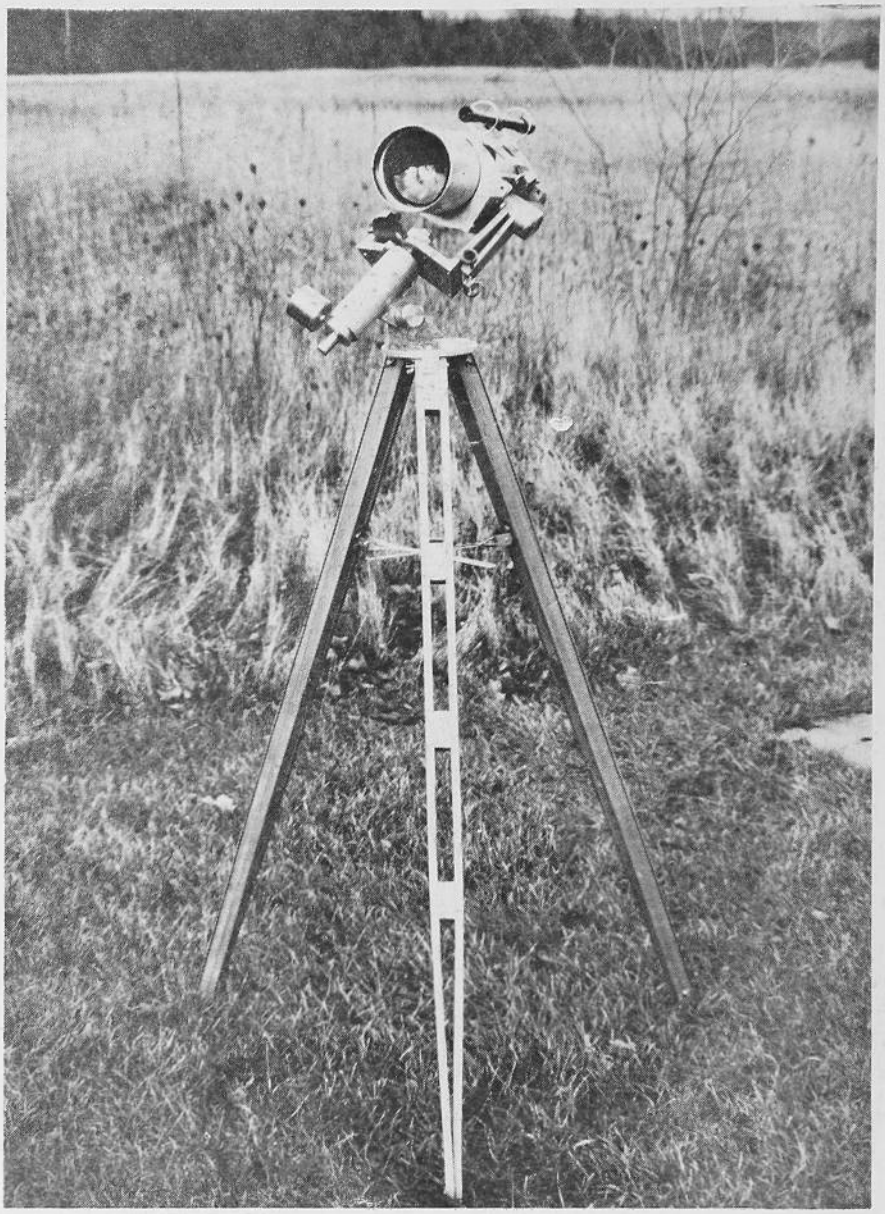
— This article was prepared by Mr. Maxwell as part of a science fair project for Dundee High School, Dundee, IL.

Making a Compact Maksutov



The primary reason I chose a Maksutov optical system for this telescope was the short tube. I wanted a portable scope, but that wasn't all: I wanted a telescope that was readily compatible with a single lens reflex camera, and beyond that, I was anxious to try my hand with a closed system — especially this type which boasts insignificant chromatic errors. I'm a refractor buff and had constructed several objectives, but could not resist the project in light of the color error comparison between the two types. It has proven to be most delightful in this aspect. I'm pleased with the high degree of freedom from color and the overall image quality. The bright edge of the lunar disk is black-and-white, and for practical purposes is absolutely colorless.

However, as I had not constructed this type of scope before, I was leery about getting in too deep, so I opted for a small "trial run." I couldn't find any design specifications for a small Maksutov, so I decided to scale down *Bulletin C*'s Gregory 6" f/15 to a 4" f/15.

The work was straightforward, using standard methods. To my surprise, none of the fabricating processes presented any unexpected obstacles. The radius of the corrector was controlled with a spherometer reading in 0.0001" increments with radius rods for verification of actual center of curvature placement. The center thickness of the corrector was checked with a height gauge using 0.0001 indicator against Jo blocks.

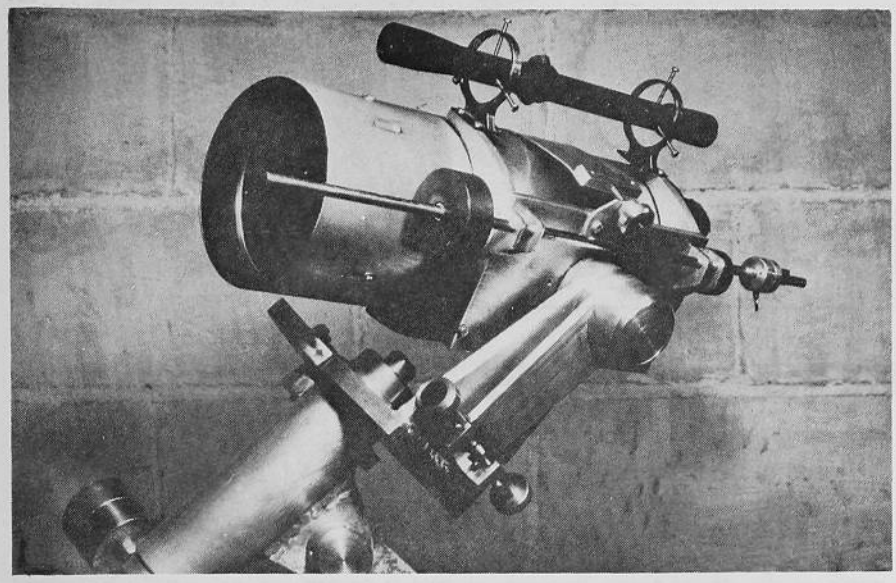
Rather than concentrate on what went right, I'll continue by covering the points that caused me most trouble. For convenience, because of the short radii, I used cement tools for the corrector. I'm really impressed with the tools made of 100% Portland; the only problem worth mentioning is that the porous nature of the cement tends to cause bubbles to rise into the epoxy used to adhere the tiles, and creates a rough surface. Later while grinding, abrasives tend to collect and stick in all of the rough places, and thus you run the risk of contamination. I recoated all channels after some initial work revealed this problem, after which the channels cleaned up very nicely. I have since coated the cement first, and after that cured, gone ahead with the tiles, and it was a smooth job.

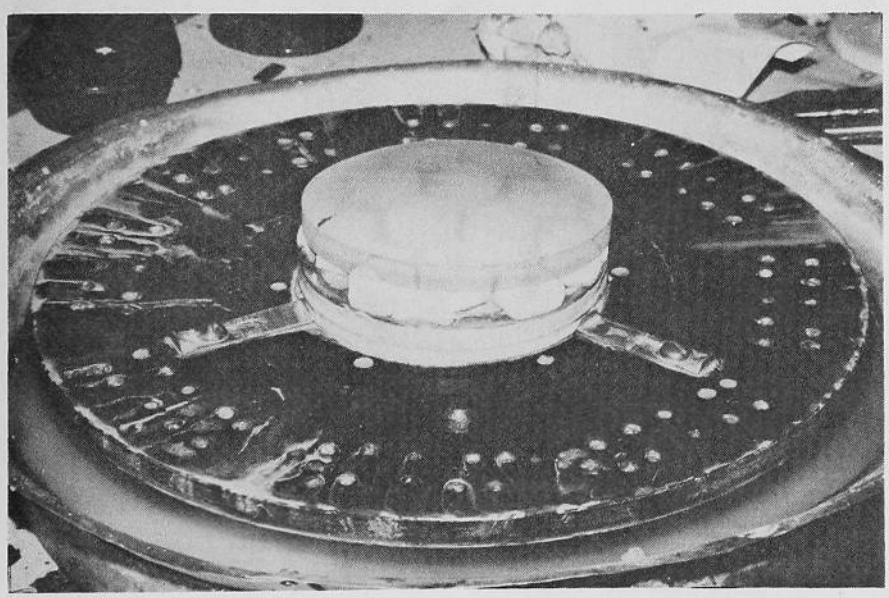
I'm sure a lot of the bubbles have to do with the type of epoxy used. I finally settled on a Hysol product, E-A 9410. This is a filled epoxy and it's very creamy. It sets with a very smooth surface — with minimum bubbles.

I found the major problem to be in the testing of the system. I worked to very close specs in order to prevent the reworking of surfaces later, but to no avail. I had to aspherize the primary anyway. Testing proved to be a real obstacle because of the spacing dimensions between the corrector and the mirror.

I knew where I wanted the back focus to be, so I adjusted the corrector position to achieve it. The final placement of the corrector was 0.030" from the designed position, causing a ¾" shift in focal plane. This may have been a factor in the amount of aspherizing required.

Test fixture rigs proved to be a real nightmare. I built two different ones before giving up on shaky contraptions and using the telescope components themselves as the test bed. Once I did this, I had no trouble in reindexing everything after each figuring spell. I just recollimated the optics in the scope itself, and then placed the tube in a "V" block set up with a flat for collimation.





The corrector blank on the grinding machine turntable, with a cement tool covered with ceramic tiles.

This setup worked so nicely compared to building a special rig, that from now on I'll save the time and effort of test equipment on this kind of project.

Testing could not be done until the spot of reflective coating was applied to the corrector. I tried every sort of light source, but reflections off two plain glass surfaces just did not come up to visible limits for me. Ronchi bands were simple to see compared to Foucault. The delicate detail was most difficult, if not impossible. I had much better luck on a star with Foucault.

During testing, I soon found that the whole thing was very sensitive to corrector tilt. The Ronchi bands would curve, so as figuring approached the final stages, I would check it outside on a star to be sure the corrector was square to the axis. The star patterns would show this immediately, of course, even though the figure was not yet up to par. For a time I thought I had some astigmatism until I became aware of alignment sensitivity.

Perforation of the primary was done on my grinding machine, with an attachment over one of the faster spindles. The operation was trouble-free, and cut to within 0.100″ of the surface. This was done before fine grinding was completed. When polishing and figuring of the sphere were completed, I finished cutting out the plug from the front side, to prevent any chipping. This, too, was completed without incident. The work must be carefully aligned to do this or a mismatch of bores will result.

Figuring was done with pedal laps having the center missing, and with subdiameter star laps. The central hole caused no figuring problems, and that portion of the surface required no retouching.

The above covers the only problems worth mentioning.

Acquiring the materials to construct the mounting was a challenge, but I did succeed in scratching up everything free of charge and did all the work myself, so I got away putting very little money in it. All major pieces are of 6061T6 stock. The polar axis is ¾″ diameter stainless steel and is cut similar to a shoulder bolt on the top end with a tangent arm and friction knob on top of that to apply the desired drag. The bearings are pressed in roller type. The declination axis is 4130 heat-treated steel cut similar to the polar axis shoulder bolt design. It has an adjustable friction drag coupled through the tangent arm.

The slow motion screws were made very simply and work to full satisfaction. I centered up a piece of stainless steel lead screw from another gadget and bored a hole to accept a stainless steel shaft. Then using epoxy, I fixed a short threaded portion of the lead screw in place.

The mating brass pieces are easy to construct. Just figure your thread sizes and calculate a spacer block of aluminum. This creates a sandwich of brass plate/aluminum/brass plate. Drill a pilot hole down the center of the aluminum, and tap the hole with a modified tap having much clearance ground off after the threads, so as to allow a deep cutting depth and thus a longer portion of usable screw cut on the brass. These plates bent around the radius of the tangent arm and present a thread engagement to the lead screw. Assuming this screw is accurately centered, the fit can be adjusted to give a very smooth action.

The mount is as small as I could make it, and as a result, the pole star is not within reach, but this is not required, for I observe planetary objects only. Observing with this short package has really delighted me, as I've lived for years in the realm of the f/15 long tubes.

Of course this scope is not for serious observation, but it has brought back a feeling of fun, and it's so easy to move around or take with me on outings. I can see no reason why I could not have constructed a 6″ or 8″ on my first try — except, of course, that I wanted a smaller scope in this case.

I'm happy with the whole venture.

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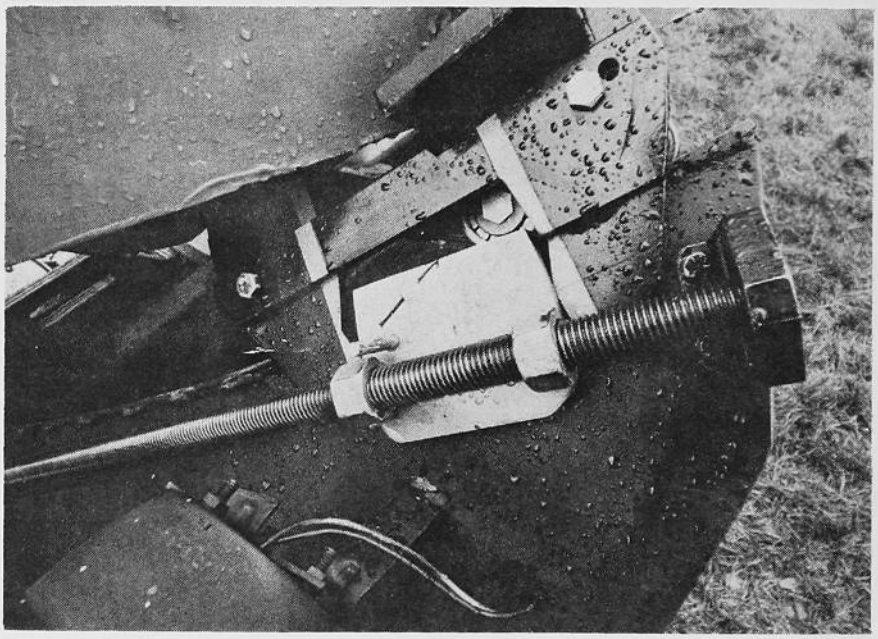
The Double Hamon Cam Drive

A New Drive for Large Telescopes

Providing equatorial tracking for Dobsonian telescopes is a challenging proposition. As pointed out by Dick Houskeeper in his article in TM#14, "a Dobsonian is, by definition, a stack of stuff held together by gravity. When the gravity vector is allowed to tilt, strange things happen." Furthermore, the center of gravity of a Dobsonian telescope and its rocker riding atop an equatorial platform is high above the axis of rotation (polar axis) of the platform. Tip it far enough, and as Houskeeper put it, "...finally the whole thing will tip off onto the ground." The very largest telescopes are the most susceptible to catastrophic tipping.

The solution to the first problem involves designing the Dobsonian scope to be stable and non-flexing upon tilting. The solution to the second problem requires rethinking the Poncet mounting to allow a lower center of gravity than provided by the conventional Dobsonian instrument. How I solved these problems to obtain equatorial tracking for a mobile, massive and long 22″ f/7 Dobsonian telescope is also described in TM#14, on page 10.

I would now like to report on the drive I have developed for this telescope. Two years ago, I began thinking about what would be required of a suitable drive. When this telescope is slewed in right ascension, roughly 900 pounds are in rotational motion around the polar axis. The design of the platform insures that the telescope will remain safe against tipping, however, because its center of gravity is located *below* the polar axis. But this positive stability, while providing safety, requires that the drive must perform considerable work against gravity. In addition, the drive must be capable of handling large loads opposed to the direction of drive motion, as well as loads that pull it in the same direction. These requirements all point toward a very strong drive.

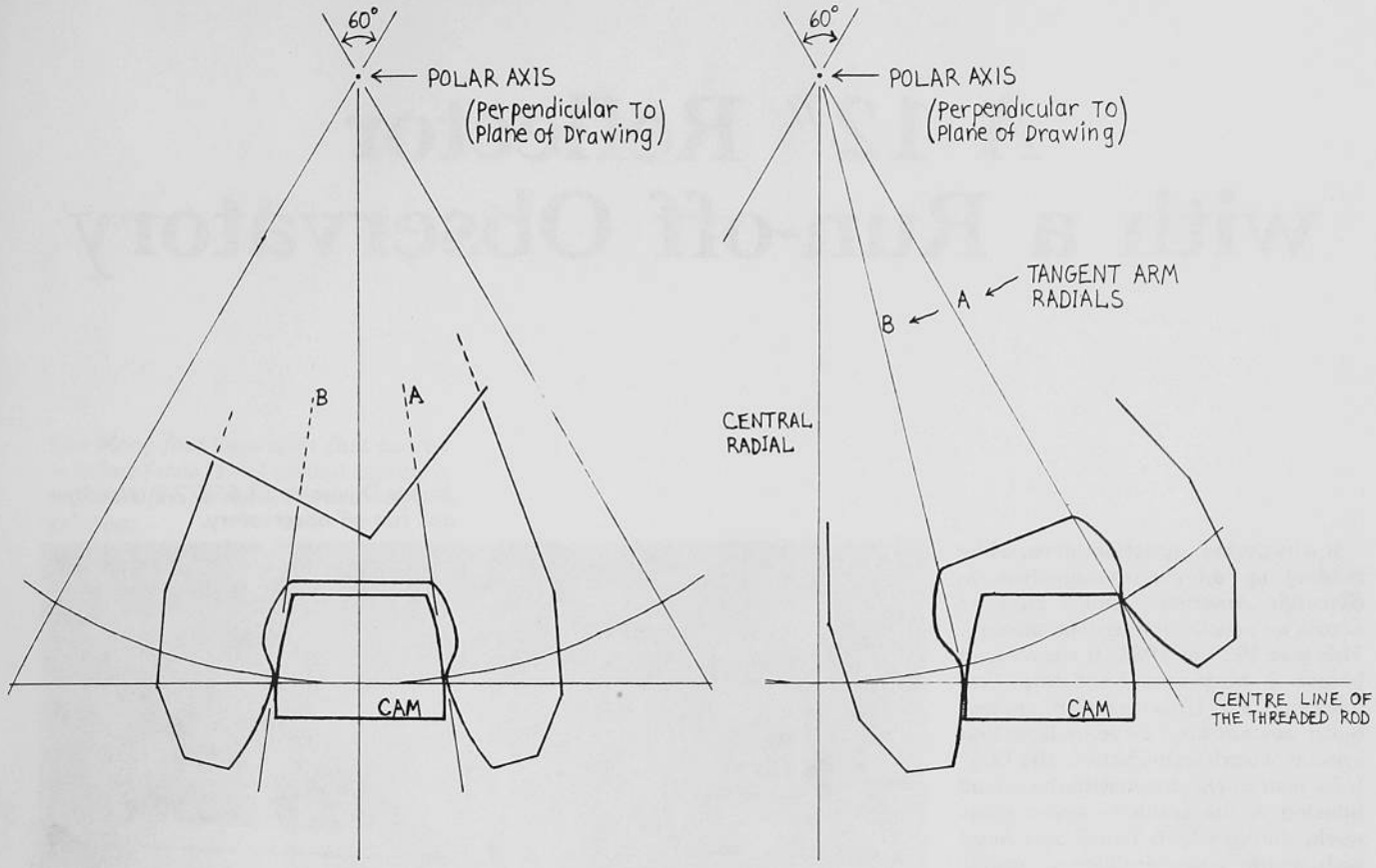


My current drive possesses strength enough that I can climb up on the driven portion of the instrument with the drive running without disturbing the centering of the object being viewed or causing the drive motor to complain!

What's the secret? At the heart of the drive is a pair of cams which work together to change the constant linear motion provided by a threaded rod into uniform angular motion around the polar axis. One of these cams slowly advances, driven by the rotation of the threaded rod. The other cam is attached to the end of a tangent arm. The tangent arm thus advances in the equatorial plane rotating around the polar axis at a constant rate. The tangent arm need not extend all the way from the cam to the polar axis — its motion is exactly the same when it is truncated where it meets the moving part of the equatorial platform. The photos show how the stubby tangent arm of my drive ends where it runs into the equatorial ring of my modified Poncet platform. A procedure for generating the two compensating curves was described by Andre Hamon in *S&T*, June 1978, p. 530.

Unfortunately, a scaled-up version of Hamon's drive (see TM#17, page 31 for a photo) did not work for my telescope. The cam and the curved tangent arm would not stay in contact because of friction and the varying moment of the off-axis weight. Adding tension members between the cam and tangent arm only made matters worse.

After much thought, I realized that Hamon's curves could be "reflected"



The Double Hamon Cam Concept

These drawings show the two-sided cam and twinned-up tangent arm in the central position and near the starting position. The curves on one side of the central radial are the mirror images of the curves on the other side.

Two hours of drive operation will carry the tangent arm radial "A" from its earlier position up to the central radial. In practice, the cam is narrower than seen here (i.e., the angle between the two tangent arm radials is much smaller), and nearly 4 hours of tracking are possible.

Unfortunately, the geometry of my telescope mounting permits only 80 minutes of tracking before resetting, so the photographs show far less curvature than the examples here.

The dotted lines in the central position drawing indicate that the tangent arms are not physically present above the point where they intersect the moving portion of the equatorial platform or ring.

around any line passing through the polar axis and perpendicular to it, to produce *two* pairs of cams which remain in constant contact throughout the drive range. The cam becomes a "two-edged sword" and the tangent arm is "siamesed" with its own mirror image. As the drive operates, although one sees angles and spacings change dramatically, the cam is never squeezed by the caliper-like ending of the tangent-arm pair, and its two faces never lose contact with their mating curves.

I used a ¾" threaded rod to support the drive cam. It is firmly mounted at both ends in sealed ball bearings fit into brackets bolted to the inclined structure at the north end of the mounting (which is also the back of the trailer). The rod is turned by a 42-watt 5.76 RPM synchronous motor through a differential which reduces the speed by a factor of two. The cage of the differential is spun by a DC motor for slewing and fast return of the cam back to its starting position.

The length of the radial line from the center of the threaded rod to the polar axis is 62", so the cam advances about ¼" per minute. For travel, I separate the tangent arm pairs by removing two bolts so that the cams won't be subjected to road shock. The telescope has now traveled some three thousand miles on the back of a trailer without damage to this drive mechanism.

For power, a 12-volt auto battery is permanently installed in the substructure of the mounting (which is also the trailer bed) and feeds the drive corrector. The corrector which was built according to a circuit published in the *Journal of the RASC Newsletter*, December 1977, by Alphonse Tardif of Quebec City. It was built for $15.00 by Giles Gaudet, an electronics teacher at the high school where I taught at the time of the initial construction of the telescope. The corrector's leads are soldered to the battery terminals and drive motor, meaning there's one less thing to fiddle with in the dark! The corrector rides in a weather-proof foam-lined box permanently attached to the inclined north plane of the mounting.

This drive design should be useful for a variety of large telescopes, particularly those not on stationary mounts. It will provide up to 4 hours of tracking without tangent error if the design principles are accurately applied.

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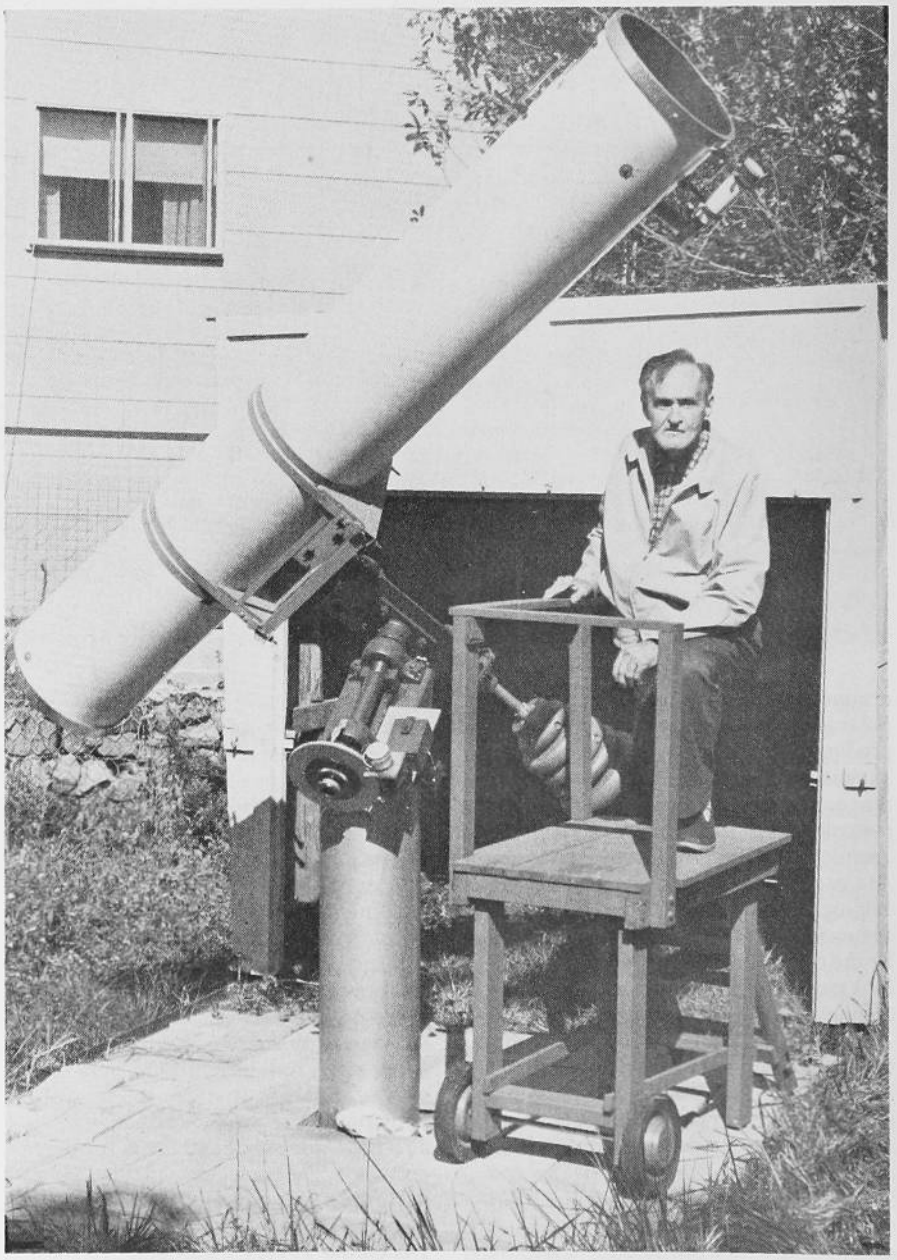
A 12″ Reflector with a Run-off Observatory

James Dawson's 12.5″ f/7.7 telescope and run-off observatory.



It was during my school days, while reading up on electromagnetism in *Scientific American*, that I chanced across an article on telescope making. This was 1933 or 1934. It wasn't long before I had completed my first telescope, a 6″ f/8 with pipe mounting, but it was not until 40 years later that I resumed work on my hobby. The 12.5″ f/7.7 instrument shown with the run-off housing is the result of seven years work, during which time I was beset with nearly every problem in mirror making, mounting and telescope housings written about in TM books.

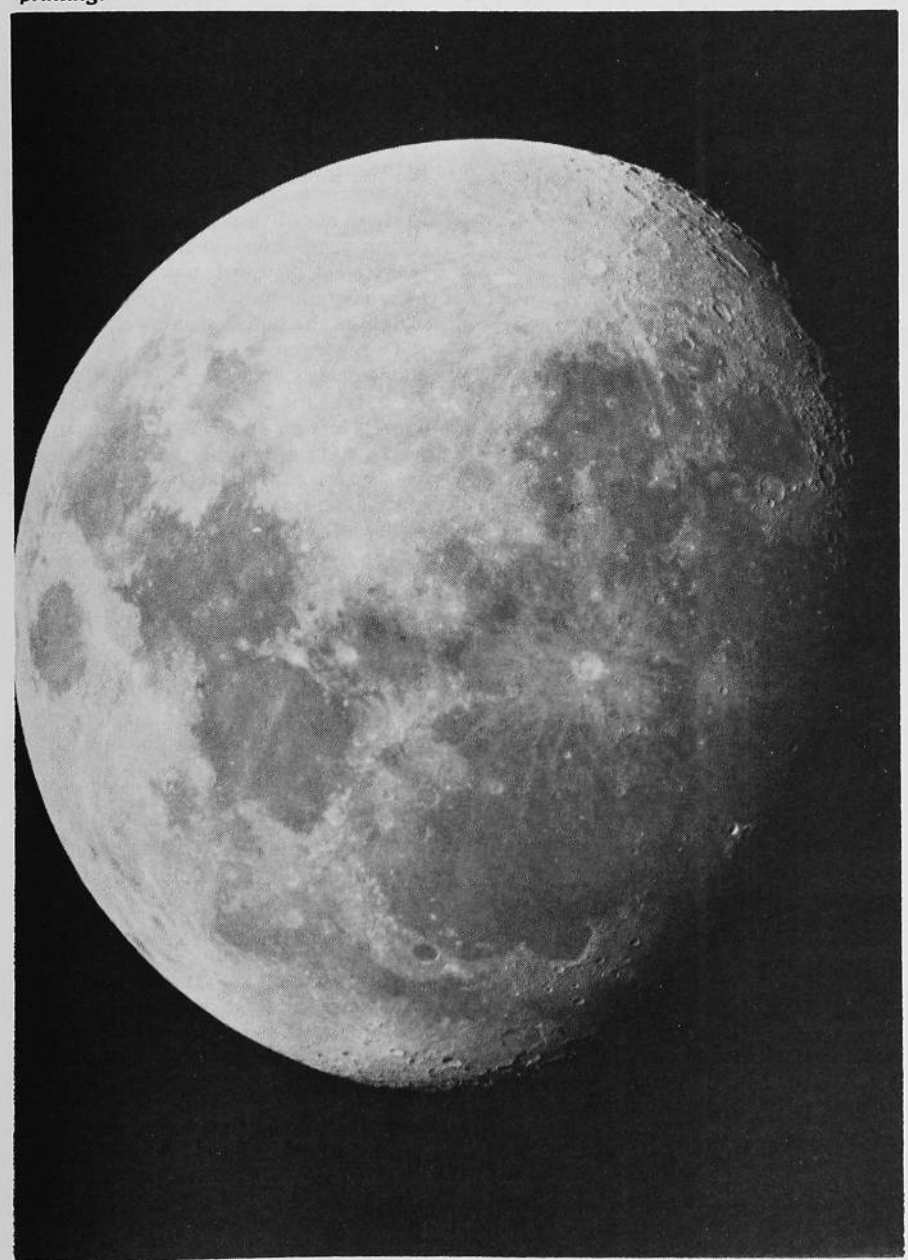
I'll admit that most of the problems I encountered were due to insufficient experience in working smaller mirrors prior to tackling a 12.5″ mirror, or rather, in relying too much on my memory of the meager experience I had acquired while working that 6″ plate glass mirror years earlier, with only the Ingalls book on telescope making available. There were times when two favorable qualities I developed over the years — patience and persistence — seemed to be dwindling.

But I did keep a meticulous log of every operation which should raise some eyebrows and put a big grin on other telescope makers. The pamphlet included with the 12.5″ mirror kit indicated average time to complete the mirror was 48 hours, but my time, without Foucault zone testing or other special tests, was much greater:

grinding — 49 hours
polishing — 29 hours
figuring — 101 hours
cooling — 141 hours
cold pressing — 207 hours
release mirror frozen to lap — 36 hours
lap making — 120 hours
Total time — 683 hours

Total number, Foucault zone test readings: 2252

The Moon four days after first quarter — prime focus, 1/60 second exposure, on Plus-X film, drugstore processing and printing.



The pyrex mirror finished at 12.125″ clear face, focal length 94.25″, computed 1/12 wave correction, no TDE, beautiful polish and figure.

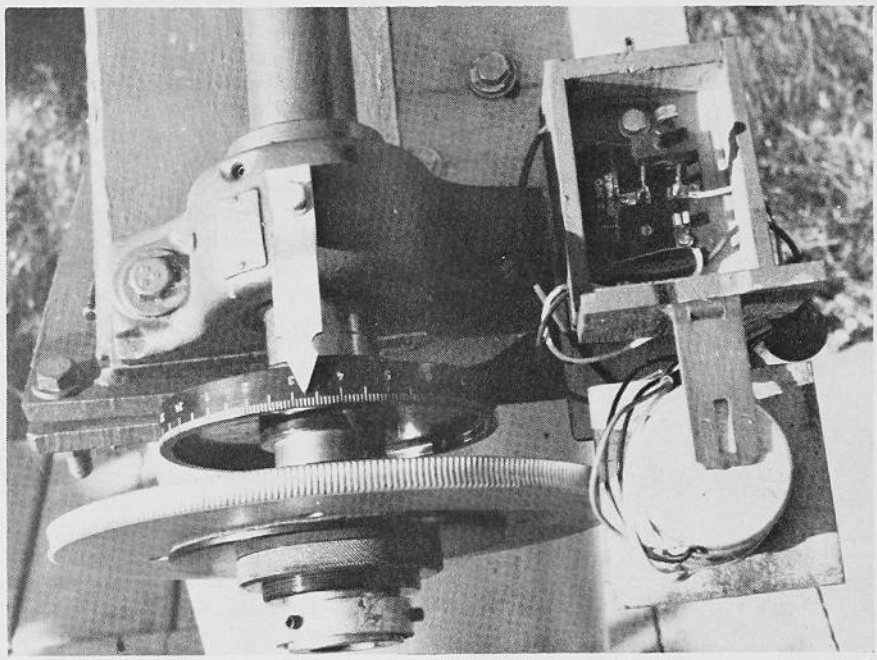
The Equatorial Mount

I was fortunate in obtaining not only a discarded 10″ x 84″ x 3/8″ wall pipe delivered free-of-charge by a sewer contractor, but also a triangular equatorial wedge of 1/2″ steel, approximately 41° angle, with matching adjustable plate for aligning with welded pipe plate, push and pull tappings for bolts, two hollow-core 2″ shafts, flanges, roller bearings and declination plate — all without cost from a machinist acquaintance, who explained that these parts and material were used and represented excess baggage around the shop while his labor was his own spare time. He suggested this type of mount instead of the large-diameter pipe that I originally questioned him about. I based the design of the triangular wedge on an article published in "Gleamings for ATMs." I had only to install the pipe pier pointing north by observing the direction of the shadow of a plumb line at local noon.

Thanks to this help, it seemed like the job would go quickly. The direction of the track for the run-off observatory would be in line with the polar axis. Then the run-off observatory could be constructed and finished, and the mount parts assembled. Lastly, I would mount the completed tube with all the optical parts.

These were my plans. But two months later, in June 1977, an article published in "Gleamings for ATMs" related the author's problems with insufficient support for his 12″ Newtonian on a German equatorial head. His counterweight, he said, had to exceed 100 lbs. so the 2.4″ declination shaft carried more than 200 pounds. Photography was impossible and visual

Mathis 10″ power drive, setting circles and protective switch box.



work difficult. Although the author did not indicate anywhere in the article the focal ratio or tube construction of his telescope, I had no way of comparing his 12″ with mine — other than that 2.4″ shaft against my 2″ shaft. I had no way of checking whether or not mine, which was also hollow, would be adequate without first completing the run-off and assembling the mount, which I estimated would take about a year to complete.

This really bothered me. I was concerned and I couldn't shake it off, but it was only a possibility as other problems started to unfold.

After the run-off was completed, I assembled the mount parts as planned, but when I came to attaching the fiberglass tube (15″ inside diameter by 96″ long) with the optical parts (a total weight of some 70 lbs), I needed the help of 2 or 3 more persons. Work was delayed for from 3 days to 10 days every time the tube or mount had to be dismantled to correct a problem. This occurred at least six times.

After the instrument had been set up, the changes, corrections and additions were: drilling and tapping both axes for set screws to prevent any part from slipping; holding the tube to the cradle by two 1″ steel straps, one of which is felt-lined for tube rotation; adding an camera support to the tube (I have so far taken lunar photos at prime focus with a 35mm body without any noticeable vibration or the necessity of clamping camera mirror, and plan on developing my own B/W film at some future date); installing wood block and friction material on both axes; and adding a Mathis 10″ drive with 6″ setting circles. The total weight of the instrument, including its pipe pedestal, is about 1000 lbs.

Run-off Observatory

The maximum dimensions allowed without obtaining a city permit and coming under the jurisdiction of the building department were 64 sq. ft. ground area and 7.5 ft. high, constructed 2 ft. inside property lines. My observatory's actual outside dimensions came to 9′ x 7′ x 7.5′high. A set of four 3″ casters limited the total weight of roll-back to 500 pounds, so I used a bathroom scale to weigh all the lumber.

Its construction consists of an upright frame of 2x4s with doubled 2x4 lower sills and a single sill on top supporting 2x3 crosspieces. The roof is corrugated fiberglass panels; the sides and back ⅛″ Masonite panels; and on the front, double doors made with Masonite on 1x3 furring strips.

The observatory rolls back on casters along 2″ x 2″ x ¼″ angle iron tracks 20 feet long supported by twenty-two 6 x 6 x 24″ concrete piers. The track is tied to concrete piers by round-head bolts. All four corners of the sill are tied down to the pier by turnbuckles with hooks for windstorm protection. When I realized that I could not stay within the recommended weight limit of 500 lbs, I installed a third pair of casters, increasing the limit to 750 lbs. The final weight of the building came to 607 lbs.

The structure withstood several windstorms since its completion in 1977, even the blow of August 10 of that year. Nobody identified the type of storm, but our borough, Staten Island, was hit hard. Three trees were felled on our block, one of which — a 50-footer with an 18″ trunk — came to rest on top of my run-off!

A tree removal contractor promised to remove the tree in the morning, but he would not take responsibility for any damage that might happen to the tube and optical parts. Late that night, several neighbors ventured into the structure to remove the tube and carry it into our living room. The next day when I checked the damage, I was surprised to find that only one fiberglass panel had been ruined despite that fact that the tree hit hard enough to drive the track on one side from ½″ to 1″ deeper.

I had to wait about 10 days for the claims adjuster to inspect damage. Instead of hiring a contractor to raise the track, I suggested a settlement covering cost of labor and material for replacing the panel and reinforcing the roof, plus cost of cable pull hoist (about $100). The hoist now makes it easy for one person to pull back the run-off. Although the size of the casters determines the difficulty in rolling the structure, larger casters would cost at least $100, whereas the 3″ size cost $5

apiece for six. Prior to the windstorm, I was able to push the housing back and forth myself, but after the damage to the track, I have had to use the pull hoist or obtain the aid of another person.

I have worked on this project from mirror making to run-off housing alone — with only TM books to guide me — through all phases of construction. I would have welcomed another ATM to work with or confer with on ideas. With this thought in mind, I joined the AAA of New York, but their meetings are in the evening and held in midtown Manhattan where traveling is both hazardous and inconvenient from our borough. I enrolled in the astronomy course at S.I. College in the evenings, completing the course in two semesters. Here I hoped to meet amateur astronomers and telescope makers, but to no avail — the instructor told me that most students take the course only for credits.

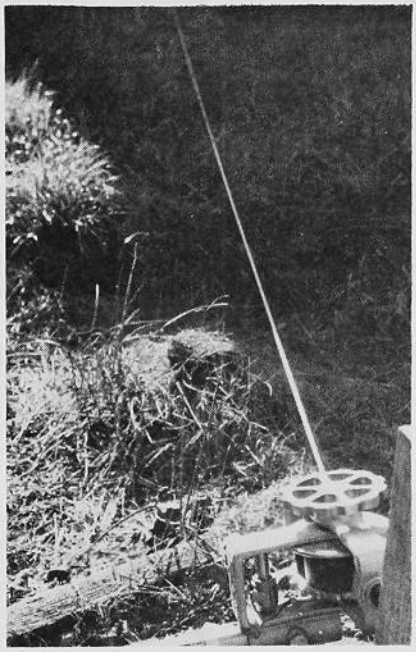
Since I was forced into retirement in 1972 at age 64 because of a slow recovery after a major operation, my wife and children encouraged me to resume my hobby of telescope making and to help influence my decision, contributed for TM books, magazine subscriptions, equipment and even a 35mm camera (which TM's associate editor, Bob Cox, recommended). I later realized that my family's motive for influencing me to become involved in my hobby again was planned for its therapeutic value in adjusting to the change in life style and an accelerated recovery. It accomplished all that and more.

Access to the sky is very limited so much so that I am practically confined to lunar and planetary work. Light pollution is another major problem in my location: houses, trees, and lights seem to have sprung up all around me. To the south, there is only the space between our house and our neighbor's, some 20 feet, with the telescope 50 feet to the rear.

On July 6, 1982, I set up my instrument with 35mm camera and Kodacolor 400 film for prime focus photos of the total eclipse of the Moon. My first shot — and the last — was the Full Moon just before the start of eclipse, as the Moon disappeared from view behind our neighbor's house! I hadn't anticipated the low elevation of the Moon in the southern sky. I waited until after 3 a.m. hoping that the Moon would reappear on the other side of our house; in the meantime, we watched the event from the front of the house before packing up for the night.

I have filled in available time by refiguring the old 6″ f/8 plate glass mirror from 40 years earlier; it was overcorrected. I've also completed an 8″ f/5 mirror. I plan to make both of these telescopes more portable with Dobsonian mounts, and will then be able take them to a location with a more extensive view of dark sky (I am still on the lookout).

The cable hoist connected to an eyebolt on the run-off and a concrete pier at end of track.



A 50 ft. tree with 18″ diameter trunk resting on west side of run-off after severe wind-storm leaving minimum damage.

Although I have had a tough struggle, I have no regrets. If I had to do it all over again, I would: 1) set my permanent mount in a more desirable location; 2) not use roller bearings intended for use in high speed operations; 3) use the Ronchi test as advocated by Dr. Schultz (his "Macalester Method" cut down my time on the 8″ f/5 mirror) in conjunction with Foucault method for testing; 4) substitute larger setting circles; 5) substitute simpler track supports for the 22 piers; 6) use an equally heavy observatory but larger casters; 7) make the lift-off doors with same construction, but in three parts instead of two, to make lifting easier. Looking back at the project, I still picture myself on bended knees digging 22 holes for those concrete piers with small hand tools, or handling the 25-pound mirror, especially near completion, besides plenty of other laughable situations in the long drawn-out production.

I would like to hear from other problem-ridden TMs so as not to feel alone in my present dilemma. I would also appreciate any information on simple methods for adapting my 35mm SLR camera to eyepiece projection for planetary work. I've priced the ready-made units but they're beyond my budget, and I am not a mechanic in any sense of the word. All my experience has come from working with hand tools.

James P. Dawson
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■

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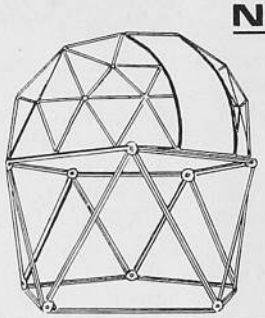

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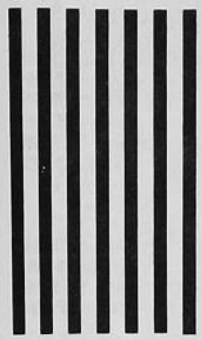

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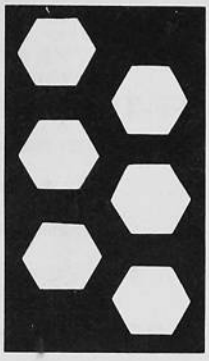

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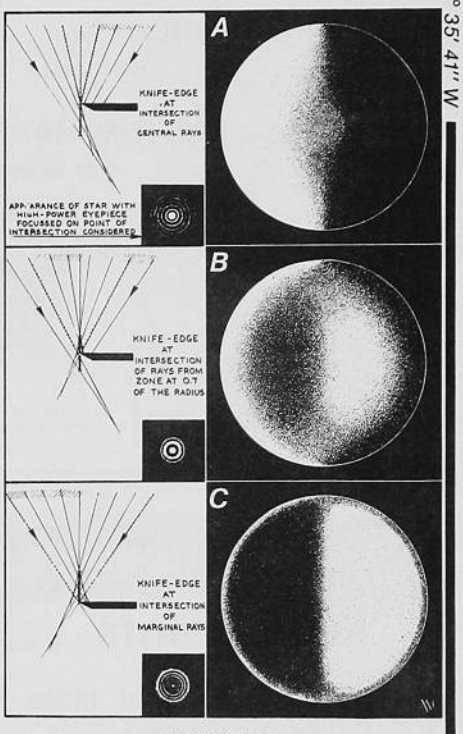

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40mm Wide-Field, "awesome" (65°) . . . $250
4.8mm Nagler, 82° field $125
9mm Nagler, 82° field, "the best" $195
13mm Nagler, 82° field, 1¼" or 2" $220
(apparent field of view in parenthesis)

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The LUMICON SUPER-FINDER is both a compact Rich-Field Telescope and a magnificent "Super-Finder". It has a fully coated 80mm achromatic lens and 300mm focal length. The Deluxe SUPER-FINDER has a superb 500mm f/6 air-spaced lens.

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2" SUPER-FINDER w/ 1¼" adapter . $139.50
2" Right-angle SUPER-FINDER* . . . $169.50
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2"/1¼" DELUXE SUPER-FINDER* . $249.50
**Requires a 1¼" or 2" star diagonal*

1¼" star diagonal, 30mm aperture . . $26.95
2" LUMICON mirror-type star diagonal, threaded for 48mm filters . . . . . **add $89.50**
Mounting rings, 3-5/8" I.D $16.95/pair
Mounting adapter for C-8, Meade etc . . . $35

NEW! ENHANCED SILVER DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 13" & 3.1" enhanced silver diagonals.

The new LUMICON diagonal mirrors have a special enhanced silver coating with a protective overcoating for long life. Visible reflectivity is 98-99% compared to 86-89% for standard aluminum coated mirrors. The extra 10-12% transmission is like adding an inch of aperture! The substrate is fine annealed pyrex flat to 1/8 wave.

Diagonal Size	Price
1.32" Minor axis	$29.95
1.52" Minor axis	$34.50
1.83" Minor axis	$39.50
2.14" Minor axis	$47.50
2.60" Minor axis	$59.50
3.10" Minor axis	$79.50
4.25" Minor axis	$129.50

ENHANCED SILVER STAR DIAGONALS

LUMICON 2" Star diagonal with enhanced silver mirror.

90° star diagonals with above enhanced silver mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror) $79.50
2" (1.83" mirror) (see photo above) . . $119.50

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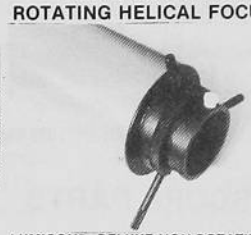
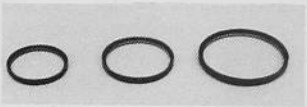


LUMICON® DELUXE NON-ROTATING HELICAL FOCUSER on a SUPER-FINDER. LUMICON has just designed a deluxe smooth helical focuser with non-rotating 2" I.d. eyepiece holder. It has a vertical travel of 1¼" and a very low profile only 1¼" high. It is CNC machined, black anodized, and a perfect match to a LUMICON Newtonian EASY-GUIDER.

Select your desired base-plate shape!
Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 20" OD, SUPER-FINDER base plate.

LUMICON Deluxe Helical Focuser . . $69.50
3 handles (see photo) $12.95
Helical focuser with 3 handles $79.95
2"/1¼" adapter w/48mm filter threads $16.95
2" LUMICON EASY-GUIDER $139.50

NEW! GIANT LUMICON® DEEP-SKY FILTERS



48mm, 58mm, 72mm DEEP-SKY Filters

LUMICON now offers its high performance **DEEP-SKY Filters** in larger sizes. They allow **both** color & B&W photography with larger telescopes. Light pollution is reduced 3-6 fold, stellar images improve and emission nebulae have increased red contrast.

DEEP-SKY FILTER	PRICE
48mm (46, 49, 52mm add $6.95)	$99.50
58mm (55, 62mm add $6.95)	$129.50
72mm (67, 77mm $6.95)	$149.50

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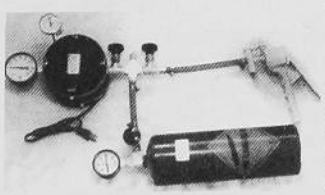
FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15X film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

†Patent Pending

MODEL 100 HYPER-KIT for 35mm film, rolled-up. *Takes longer,* but it easy to use. Not recommended for 2415 . . . . . $225.00

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds $275.00



MODEL 600 HYPER-KIT [See Photo] Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates $299.50

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller . . . $525.00

Temperature controller for any HYPER-KIT $59.50

Electric Vacuum Pump $265.00

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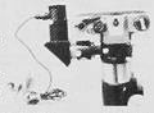
All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms fo bright guide-starts. *Specify Camera and Telescope type.*

†Patent Pending

NEWTONIAN EASY-GUIDER™



Full aperture. Installs in secs. Specify 2" or 1¼".
NEWTONIAN EASY-GUIDER $139.50
3X Relay Diagonal [See Photo] $59.50
Illuminated reticle eyepiece system . $59.50

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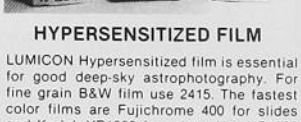
GIANT EASY-GUIDER $359.50
48mm DEEP-SKY Filter ordered with any EASY-GUIDER [SAVE $20] . . . . . **add $79.95**

WHAT DO YOU NEED?

1. Hypersensitized Film. Use a LUMICON HYPER-KIT to insure a fresh supply, or use film pre-sensitized by LUMICON.
2. LED Illuminated reticle eyepiece system and battery pack, dual crosslines . . . $59.50
3. Telescope with good drive. (See above)
4. Piggyback adapter (state telescope type)...$25 Deluxe adjustable $39.50
200mm f/3.5 multicoated lens $99.95
5. Filtration is essential for all lenses. Use hypered 2415 and the H-Alpha Pass Filter. For III a-J or color, use the Minus Violet Filter or the LUMICON DEEP-SKY Filter.
6. Off-axis guider is **essential** for consistently good prime-focus astrophotography.
7. Dual-axis drive corrector and electric declination (state telescope type) $259



HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. For fine grain B&W film use 2415. The fastest color films are Fujichrome 400 for slides and Kodak VR1000 for prints. Use VR1000 for galaxies and Fujichrome 400 for nebulae.

Film Type (35mm unless marked)	Exposures	Price
2415, Ultra-fine B&W, red sens	36	$9.95
Ektachrome 200 prof. 5036	20	$9.95
Fujichrome 400, "Excellent"	20	$12.95
VR1000, fastest of all, color negs	12	$12.95
5072, color slides from negs	36	$6.95
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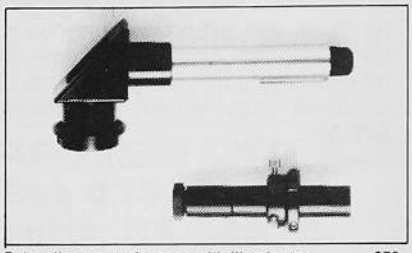

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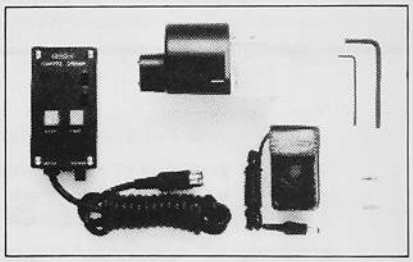

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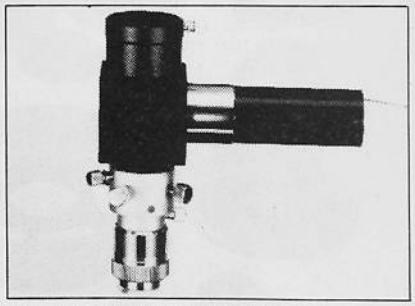

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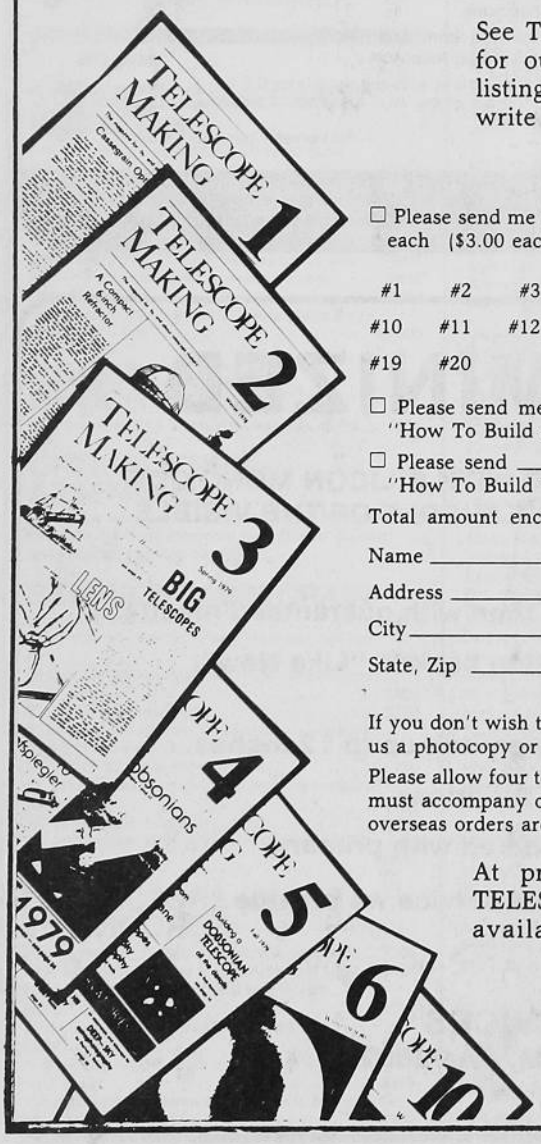

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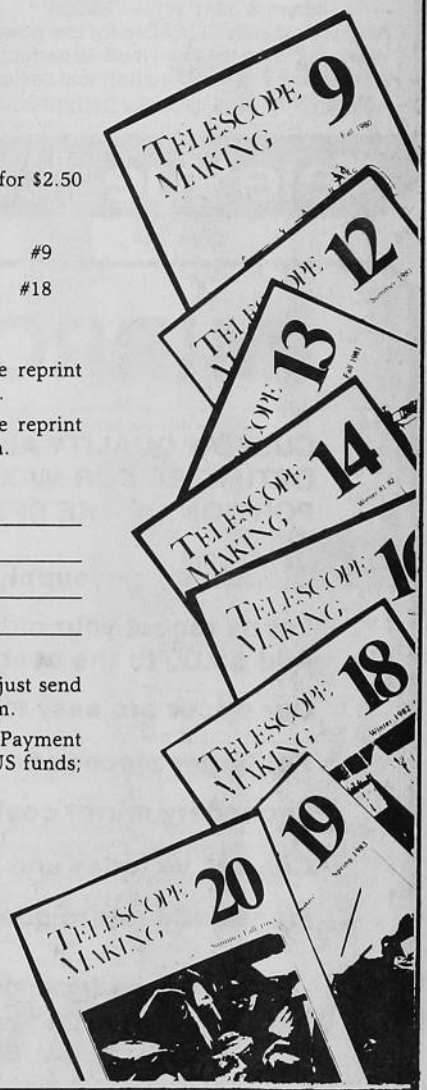

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